The strengths and weaknesses in the Swedish renewable energy sector – an assessment report

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Abstract

There are both weaknesses and opportunities of the Swedish renewable energy sector. This papers aim at increasing the awareness of how the state of the sector is right now, if there are any obvious difficulties facing firms in Sweden and provide knowledge about what issues that has to be addressed in order for firms to be able to succeed. The aim is addressed by looking at data and connecting the data to growth theory. Three issues stand out. Business angels do not understand the industry: As angel investors not only contribute capital to the company, but also its expertise, commitment and contacts, it is important for most business angels that they understand the industry to invest in. Lack of capital - access to capital is insufficient. Small critical mass - absorbing technology: In order to absorb technology human capital is needed, not only in general but specific technology.

Introduction

Given continued economic and population growth the global energy demand will likely follow the development progression in an upward pattern. An increasing energy demand will probably, but not necessarily, further burdens the nature and the human living environment (Suganthi and Samuel, 2012). To minimize global climate change, largely driven by the buildup of greenhouse gases in the atmosphere new carbon-free energy technologies are needed (Stern, 2007).

The paper aims at identifying strengths and weaknesses in the Swedish renewable energy sector. What is strength and a weakness is of course a relative term. If there are only one contender in a race the person is both the weakest and the strongest contender. In the renewable energy case there are several countries in the race. Sometimes we're more than willing to work on our weaknesses, but the problem is we haven't taken the time to identify them properly. If politicians know weaknesses in their countries which halting the development of much needed technological development then policies can be created to face those weaknesses.

The report will concern a Swedish and European context. Firstly, the general development of renewable energy in Sweden is presented. After that the Swedish development will be contrasted against the development in other European countries, both in absolute numbers and as per capita measures. Then some conclusions will be drawn by comparing the Swedish situation concerning technological development with other European countries.

While the environmental related challenges are large, there is reason for cautious optimism. Innovations are often driven by a combination of four key forces: curiosity, fear, the desire to make money and do good (Diamandis and Kotler, 2012, pp. 217-218.). In the renewable energy case the climate problems facing the world and the need to create a sustainable production and consumption contribute to strengthen these four incentives.

Emissions, just as new knowledge, cross country borders. The development of new technologies in the energy and environmental field opens a myriad of opportunities to diffuse sustainable energy outside a country by product exports and knowledge for the implementation of the international energy system. During the past 30 years the green energy market has undergone a rapid transformation, with falling costs and a prompt expansion of produced energy rate.

- In year 2013 twenty percent of the world’s production of energy was renewable, the share from renewable sources is expected to rise to 31 percent year 2035 (IEA, 2014).
- On a global level approximately 44.8 Gigawatt (GW) of new wind power was added in year 2013, making the total amount 280 GW (GWEC, 2013).
- Wind power is was in 2012 producing approximately 3 percent of the world’s energy and there are wind power in more than 100 countries (WWEA, 2013)

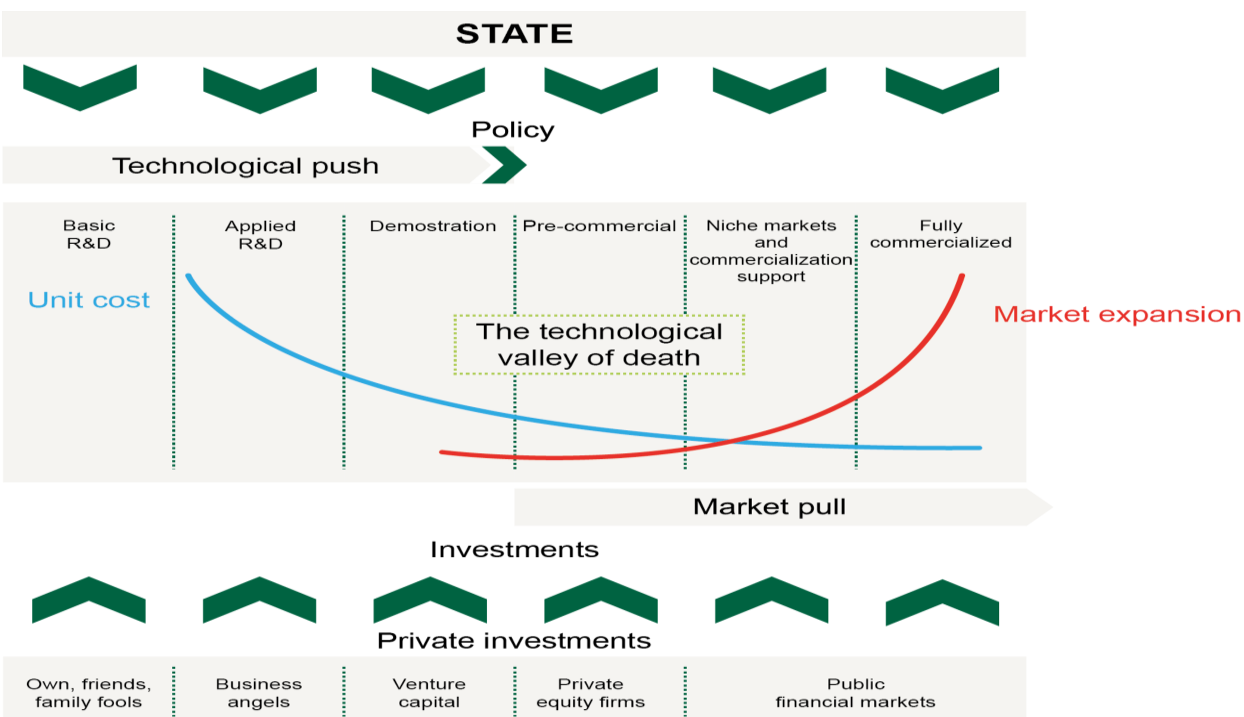
- The average investment cost, in US$ per kW, of wind power have gone down by more than 50 percent since the 90´s beginning. For solar energy the unit price have gone down with more than 50 percent (IRENA, 2012).

The rather steady increase in renewable energy output over time can partly be explained by technological progress and learning processes. There are still disagreements about the degree to which learning has pulled down the cost per unit of energy. Studies show that the overall cost per installed unit has gone down by several percent per year (Lindman and Söderholm, 2012). Energy from the wind is extracted by a relatively mature technology. Mature technologies have a tendency to lose the rate of efficiency improvement, at least for a period of time until a new major breakthrough occurred. The overall expansion of the number of power plants, however, is accelerating. Judging on the permit applications pending in Sweden capacity could be triple (Stromberg, 2013).

A key Gordian knot concerning the future of solar energy is to what extent technologies for capture and storage of solar energy continue to develop and that the cost of solar energy production continues to decline. Here, technological development, in addition to increased production volumes, will play an important role. The same applies to the further development of wind power and hydropower. Research is also ongoing in terms of technology development on wave energy, including outside the Swedish west coast

Methods

The Swedish renewable energy sector will be analyzed within a valley of death framework. The Valley of death is beside being a biblical reference and the name of the hottest area on the planet, among other things, a business literature concept used to describe the development path a firm have to go through when they have an innovation that are going to the market. The concept center on the cash flow problem a new firm have from the point that they have a product until the product reached a sales level where the firm breaks even (Murphy and Edwards, 2003). A new product generally have a high unit cost and a low market penetration due to an early oversized production capability compared to the demand at that time period. Costs can be lowered through development and learning during product production. Form many firms in the environmental energy field, it is often necessary to present a full-scale demonstration plant to convince potential customers that the product is working and that there are potential to make adjustments to fit the need of the purchaser.



Figur 1.The innovation chain and the technology ‘‘valley of death’’ (adapted from Grubb 2004; Bürer and Wüstenhagen, 2009)

There is also a degree of information asymmetry between traditional investors and producers of new technologies. Information asymmetry occurs in transactions where one party has more or better information than the other actor. Information asymmetry creates an imbalance of power in transactions, imposing transaction costs and sometimes causes the transactions to go sour. Information asymmetry is a kind of market, failure in the worst case the consequence is that no transactions are made. Information asymmetry can be corrected by early venture capitalists, which to some extent are familiar with the field, supporting businesses through the initial phases.

The environmental energy sector is typically characterized by a high degree of uncertainty. The development in the sector is very dependent on state's climate policy. Not only in the sense that subsidies paid to the environmental energy in the early stages of development keep several firms afloat. There may also be consistency uncertainty regarding the taxation level of carbon dioxide emissions. If, for example, these emission taxes are removed, by a government inclined to bring down gasoline prices, the relative prices of energy sources change, and not to the benefit of environmental energy.

Three barriers for implementation of new technology

Although many of the green energy sources has long been around many cannot be perceived as established. There are three barriers a new energy technology must cross in order to be accepted. It is a political, social and industrial in order for a technology to be getting through what the literature called "valley of death" (see figure 1) and implemented requires support measures. Without support, there is a risk that the new technology to remain a niche product, or produced in another country with better conditions (LeBelle and Goldthau, 2014).

A technology system is the environment that surrounds a technology. It consists of social, political and industrial spheres, together with the country's institutions, formal and informal. The technology system will determine how regulations affect a sector and will be a function of, in the case of environmental technology, the technologies that are already working in the sector. The energy sector is dependent on how government agencies act as these can affect the competitive situation and sometimes the technologies access into the market.

In other words, society actors - social, political, and industrial - to some extent support a technology if it is to be established. (Not necessarily money) Wüstenhagen et. al., (2007) argues that society's actors is particularly important for the energy sector. The energy sector is essentially different since the production of energy provide significant negative global externalities. A form of externality is the understanding of the operation in the environment / nature when the first wind power plant is being built in a familiar environment. Are people unprepared for the change is a risk that they sometimes, though not always, consider the plant as an intervention of their former freedom; unobstructed views.

LeBelle and Goldthau, 2014 identifies, in a study on the introduction of various energy technologies in Germany, USA and Spain, a high support from the political sphere as important for the success of technology. Further, ensuring research and establishment grants for pulling technology out of the valley of death. A fragmented political system sends signals of uncertainty about subsidies and future taxes. Investments are therefore less secure.

The industrial actors are also important for a new technology to be introduced. The industrial actors should be in a situation where they have access to capital through banks and institutions, and have a working contact with political actors. The social partners must also rely on the industrial players to their project to gain acceptance. Consumers do not have a high confidence in the Swedish electricity market (Consumer Agency, 2014), this combined with distrust of new technology and the reluctance of renewable energy can cover the demand for energy makes the expansion slower than necessary.

How support systems are designed can have serious consequences, especially if Sweden closes one or more nuclear reactors. There are shortcomings in the design of Spain's green energy transition, after the financial crisis, budget problems have led to the then promised support levels have not been retained. The Government of Spain chose to issue long-term contracts, 25 years, and allocated 6.3 billion euros. Those who sell renewable electricity into the energy system receive subsidies of up to 10 times the market price (LeBelle and Goldthau, 2014). The support led to a rapid increase in the number of installed units. Capacity increased by 500 percent between 2007 and 2008.

The technological effort that began in 2007 did not arise from a vacuum but were rather the results of a decade of discussion. From the political actors was broad support for reform in order to become less dependent on imported coal and oil and invest in renewable energy. There was strong support in the Spanish population - 83 per cent supported the idea of expanding the solar energy in Spain.

Standing on giant's shoulders to see far - knowledge transfer

It is often assumed in the spillover literature that geographic distance matter, if there is several environmental energy companies near each other, it creates a better labor market. People with different skills can meet and exchange ideas and recruited for special projects. The very idea that knowledge spreads are a cornerstone of the endogenous growth theory (basic work done by Romer (1986) and Lucas (1988)) that try to explain why we have long-term growth. Although the geographical distances may have lost in importance, Sweden has few environmental energy industry and they are scattered across the country. The geographic dispersion could potentially be negative for the growth of more and larger firms.

In technological development, there are tendencies that successful development is moving towards the same geographic areas. It will be a clustering effect like e.g. the Silicon Valley. Cluster theory implies that comparative advantage may lie outside firms and inside the geographical areas in which they are domiciled (Porter, 2000). This means that firms may have increasing returns in some areas and that this profit is dependent on others also choose to invest in the area. An example of how the pace of innovation has moved northward available in Grafström and Jaunkey (2014) in which Figures 2 and 3 show the displacement of the innovative center of gravity in Europe over time. Where there is a clear movement northward during the period 1990-2012. Per capita, the countries in Northern Europe increased the distance to the southern European countries with respect to the number of patents approved

Figure 2 Patent per capita in Europa 1990. EPO, 2014.

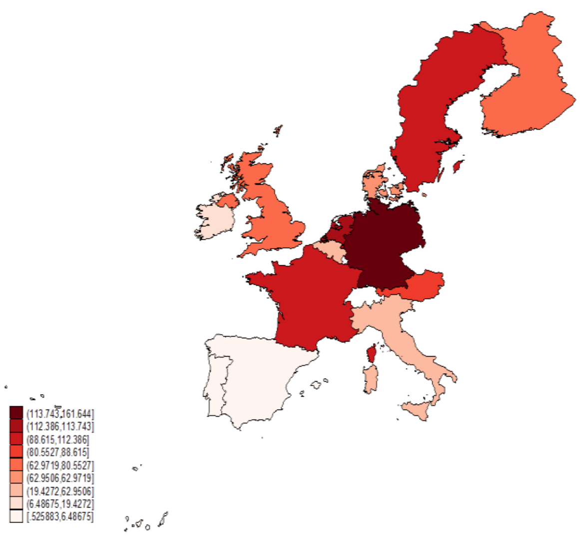
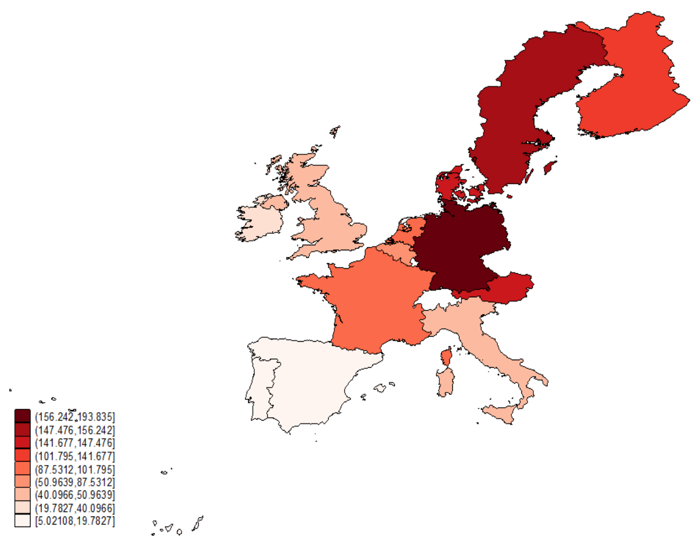


Figure 3 Patent per capita in Europa 2012. EPO, 2014.



The world innovative center moves. Something that is much more constant is the value of being the innovative center. Knowledge has the character of a "public good" that is to say that a person's consumption of it does not prevent someone else. It may even be positive spillover effects. If it carried a strong energy in the field will share the knowledge spill over into other fields.

How new technologies arise and integrate into society and thus creates new emerging industries can be studied in a variety of ways. The neoclassical economic perspective focuses on the differences in the relative prices of goods, and how it affects the market supply. For example, the cost of one type of energy relative to another's impact on the demand for the energy source and the amount of resources spent on developing new products. In contrast to the neoclassical perspective is the entrepreneur´s perspective. Individual firms and entrepreneurs in this perspective is the central object. To these two perspectives can be added innovation perspective. Innovation perspective pressed to innovation and introduction process is both an individual and collective process. It determines a company's growth is not only within the individual company but is dependent and influenced by an innovation system (Johnson and Jacobsson, 2001).

Results

In the Swedish environmental technology sector firms are either developing small firms or large firms that tend to buy smaller firms. Small firms in general often face significant growth challenges. The challenges are to no lesser extent a reality for small environmental technology firms, these firms operate in a market with high political and technical uncertainty about what kind of technology will be the industry standard in the future, if there will be a standard. The environmental energy firms in Sweden are few in numbers[1]. Data from Vinnova (Table 1) shows that in 2011 alone there were twelve in the definition of "SMEs", which refers to firms with 51-249 employees. In 2011 there was only a large company, with more than 250 employees.

Table 1. The Swedish energy firms, numbers, revenue, size. Strömberg (2013).

Number of firms	197
Number of work places	372
Number of employees	5 763 persons
Total net revenue	46 billion SEK
Number of big firms (> 250 employees)	1
Number of medium size firms (51– 249 employees)	12
Number of small size firms (< 50 employees)	184

The business segment named "renewable energy" includes four sub-groups; hydropower[2], wind, bio and solar energy. Generally, the firm population consists of small firms, or smaller firms within larger corporate groups, active in renewable energy. The corporate groups operate in many of the fields in the renewable energy segment, particularly in wind and hydropower. Larger corporate groups tend to engage in more energy fields. The renewable energy industry subgroup has a large turnover, 46 billion SEK, which is about ten percent of the entire energy industry. But the industry employs few people (Strömberg, 2013).

A own survey of the member rosters of the Swedish industry branch organizations, Swedish Wind Energy, Solar Energy and Swedish Svebio, displayed a growth compared to the Vinnova numbers from 2011, listed below. The data above is adjusted, excluding for example banks and law firms that could be a part of a branch organization even though they were more a service industry but did not produce any energy or research. However, there are firms that have a main employment in other areas yet included in these figures. An example is technical consulting company ÅF is active in several other areas. Many of the firms are also municipal firms, especially in the bioenergy industry.

Table 2 Review of the professional organizations in member firms 2015

Wind	Solar	Bio energy
133	115	+300

The Swedish environmental energy sector

Environmental technology has become a fast-growing area and the perceptions of what should be included in the concept diverge. In addition, other, related concepts such as green firms, clean tech, eco-products, environmental firms, environmental innovations and "green economy" are used (Andersson et al 2008). One definition which was introduced in the EU Commission's Environmental Technologies Action Plan (Environmental Technology Action

[1] Talking about the size of an environmental energy firm comes with at least two major challenges. First of all some firms do environmentally related projects but it is not a main area for the company in terms of their overall operations. Secondly, when it comes to determining size the number of employees does not tell the whole picture for technology firms.

[2] Vinnova's statistics include firms that produce hydroelectric power which a small number entered statistically as the heating company.

Plan, ETAP)[3], says concisely: “Environmental technology comprises products, systems, processes and services that deliver clear environmental benefits compared to existing or alternative solutions, seen in a life cycle perspective.”

It is possible, with a large extent of good will, to speak of environmental technology sector[4] as a single distinct industry type, but to measure its development is not straightforward. An environmental product may be invented, in principle, in any industry. The environmental aspect can be a positive unexpected outcome of something that the inventor was not intending when the product was developed. The Swedish environmental energy sector so far has been rapidly growing in percentage terms, just like the corresponding industry in many other countries. Between year 2003 and 2010 the revenues of environment enterprises increased by nearly 60 percent. The sales and exports however hit a temporary downturn after the financial and euro crisis.

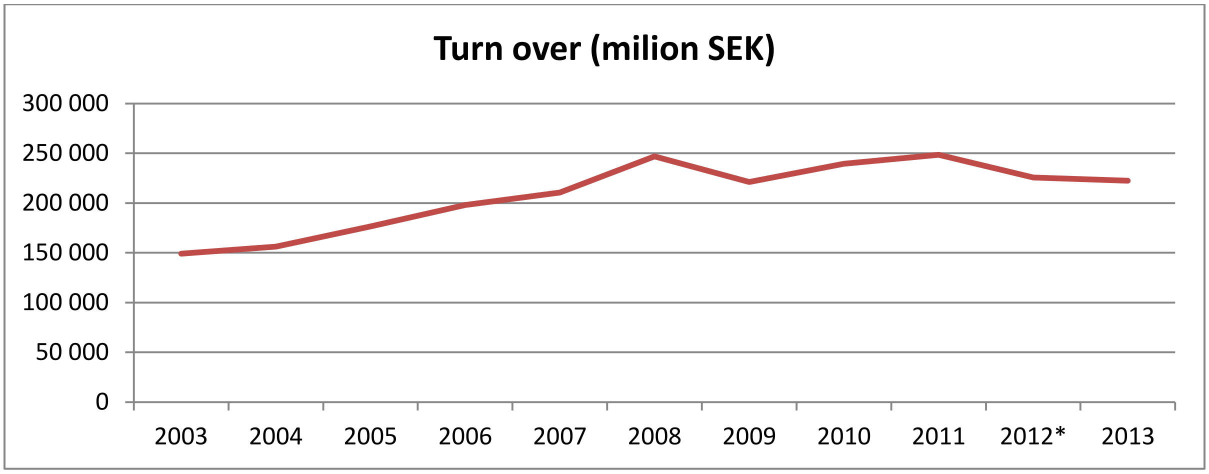


Figure 4 The Swedish environmental sector's size, SCB 2014

The number of workplaces, geographic locations where work is carried out, has not increased particularly rapidly in absolute terms compared to the other variables presented however, employment has grown steadily (SCB, 2014). A lack of growth in workplaces compared to the number of employees is expected as a workplace can be a company that is expanding on site, doubling the number of employees does not necessarily mean a further geographical spread.

The different fields of environmental sector

Table 3 shows the number of workplaces, exports and revenues broken down by energy field[5]. The category "Renewable energy sources", corresponding to this report's focus area, had in year 2013 few employees, but high turnover. The number of workplaces in the category was in 2687, making it one of the major categories. Revenue was estimated at 90 billion, a sizable proportion of the sectors of total turnover. Since year 2007, sales have increased by 20 billion and exports by 2 billion SEK (SCB, 2014). In the database each establishment is classified according to its environmental area and, based on the proportion of the activities that can be considered environmentally related. This should partly take away some jobs from the statistics in a firm with another main activity (for example, the major energy firms).

[3] http://ec.europa.eu/environment/ecoap/about-action-plan/etap-previous-action-plan/

[4] Statistics Sweden defines the environmental sector as "sector for environmental goods and services consist of activities that produce goods and services to measure, prevent, limit, minimize or restore environmental damage to water, air and soil as well as problems related to waste, noise and ecosystems. This includes cleaner technologies, products and services which reduce environmental risk and minimize pollution and resource use. "

[5] SCB works on the basis of Eurostat manual "The Environmental Goods and Services Sector - A data collection handbook" (2009)

Table 3 Sales and exports in million SEK in environmental sector 2013, SCB 2014

Environmental area	**Number of work sites**	**Turn over**	**Export**
Air Emissions Control	128	3 029	1 276
Sewage treatment	946	14 240	2 430
Waste disposal	2 757	35 168	4 478
Soil and groundwater	435	2 402	392
Noise and vibrations	39	281	--
Environmental consultant	1 555	7 691	649
Education, research and monitoring	261	1 307	98
Recycled material	1 933	38 910	11 856
Renewable energy sources	**2 687**	**90 107**	**9 142**
Heat / energy saving	901	13 692	6 187
Sustainable agriculture and fisheries	4 513	7 954	292
sustainable forest	102	6 403	29
Other (including ecotourism)	177	1 210	--
TOTALT	*16 434*	*222 393*	*37 061*

Västra Götaland has the largest number of employees in the sector, renewable energy sources; in table 4 the number of employees per county is presented. However, Stockholm has only marginally less turn over in the sector with a third less employees. Beside that counties reflect its relative size without any county standing out much. Statistics from Vinnova, 2013 showed that the Swedish environmental firms are very geographically scattered over the country.

Table 4. Number workplaces, turnover, exports and employed, per country, sales and exports in milion SEK, SCB 2014.

County	**Number of work sites**	**Turn over**	**Export**
Stockholms county (01)	1 950	34 965	3 355
Uppsala county (03)	591	4 453	290
Södermanlands county (04)	530	6 858	1 190
Östergötlands county (05)	983	15 703	3 089
Jönköpings county (06)	651	7 190	1 725
Kronobergs county (07)	422	6 185	1 528
Kalmar county (08)	550	7 045	778
Gotlands county (09)	311	838	44
Blekinge county (10)	222	3 147	1 072
Skåne county (12)	1 657	21 140	4 348
Hallands county (13)	589	5 547	860
Västra Götalands county (14)	3 181	36 955	7 430
Värmlands county (17)	668	6 088	977
Örebro county (18)	531	6 206	897
Västmanlands county (19)	500	10 919	3 347
Dalarnas county (20)	611	6 489	--
Gävleborgs county (21)	594	7 759	--

Västernorrlands county (22)	482	9 355	1 204
Jämtlands county (23)	435	6 458	228
Västerbottens county (24)	488	10 549	--
Norrbottens county (25)	482	8 539	544
Totalt	*16 434*	*222 393*	*37 061*

Broken down at the industry groups level, as shown in the table below, once again energy production generates few workplaces (1415) but a high turnover (60 billion SEK). The discrepancy between the number of work sites and employees is not unexpected. Some workplaces, for example nuclear power has sales significantly more than, for example, an organic agriculture farm. Parts of the environmental energy production are located in areas other than just main category energy production.

Industry Group	**Number of workplaces**	**Turn over**	**Export**
1 Agriculture / Forestry / Fishing	4 601	12 073	56
2 Extraction / production	1 140	41 171	18 100
3 Energy	**1 415**	**60 167**	**2 319**
4 Water / Waste / Wastewater / Recycling	1 587	38 901	4 060
5 Services	6 754	68 051	12 470
6 Public	810	1 788	45
7 HIO / PK	121	207	11
8 uncoded	6	36	0
TOTAL	*16 434*	*222 393*	*37 061*

Energy types

First, the distribution within four areas (share of the sector's turnover, employees, and foreign ownership) for renewable energy sources will be presented graphically then the sources will be presented in more detail. Bioenergy is the dominant Swedish environmental energy supplier in terms of number of firms active in the sector. The type of energy is responsible for upwards of 50 percent of production. Wind power accounts for about a quarter of the renewable production. Consequently, bioenergy is a major part of the turnover too. Water and wave power a higher turnover than the wind. Solar energy has the lowest turnover. A majority of the employees in the sector are employed in the bioenergy branch. Wind and wave/tidal power, have about the same proportion. Wind power has a relatively large foreign ownership while bioenergy has a small percentage of foreign ownership.

Wind energy: In year 2014, wind power in Sweden produced 11.5 TWh, and had an installed capacity of 5425 MW. It made up approximately 8 percent of the Swedish energy usage, the number of installed wind turbines were 3048. There was a significant increase compared to 2012 when the production was roughly 7.1 TWh of electricity. The forecast for 2015 is a increase in installed capacity of 600 MW and the number of new power plants will amount to 327 structures, a number of older people is taken away each year. There were 5138 plants under permit consideration, the planed plants had a total capacity of 16912 MW, i.e. a tripling of existing Swedish capacity at the present time. Wind power accounted for in 2011, 24% of the renewable production, 16% of net sales and 19% of employees (Stromberg, 2013).

The solar energy segment primarily contains firms that sells and produces solar cells as well as firms involved in consultancy and service. However, most of the industrial production is located in other countries, mainly Germany, which has a capacity per capita almost ten times larger than Sweden. At the end of year 2012, there was a total capacity of 32 GW in Germany 1.3 million installations. During good weather days, solar cells for stood for up to 35 percent of the electricity supply in Germany. Solar energy contributes only with 5.3 percent of the total annual consumption.

Renewable energy is often blamed of being economical unprofitable, historically that has been correct for many countries. Solar technologies have, however, reached a point where the problem seems to be over. In a number of countries solar energy is expected to reach profitability without subsidies, so called "Grid parity". These include Italy, India, Mexico, China, Spain and parts of the United States. Within the Swedish renewable energy sector is solar energy produce 11% of the energy, and represents 1% of net sales and 5% of the employees in the segment. 14% of solar energy firms have a foreign mother owner group.

Bio energy: In the transport sector, there are a number of pathways in the production of environmentally friendly fuels: biogas, ethanol or biodiesel made from, for example rapeseed, corn or palm oil. At the global level, there are criticism directed towards parts of this production with a notion that it displaces food production requires large amounts of water and areal use.

Biofuels is counted in Vinnovas study as the materials of the industry generally classed as biofuel, such as biofuels, oils, fuels, pellet and black liquor (the residual liquid obtained after completing pulp cocking or after the bleaching step.). Bioenergy is the dominant energy source in the Swedish renewable product mix. Bioenergy in the segment of renewable energy amounts to 50 %, representing 53 % of net sales, with 61% of employees.

Wave / hydro: Firms in hydropower have naturally located energy production mainly along rivers. They have stretches of secondary activity in the coastal towns in river mouth, for example a company such as Skellefteå Kraft. The technological development of hydropower is relatively motionless. Hydropower will capacity vice not be expanded further in Sweden. A number of rivers are according to political decisions having to remain untouched without any constructions. Meanwhile, the developed rivers cannot accommodate more hydropower plant capacity. In places where it would be possibly to build power plants people are living and would need to be moved, which can cause major problems.

A possible development trend in the water energy generating field is the emergence of firms specializing in horizontal and sea bound stream power which can eventually alter the growth of the entire segment when the oceans which has not been utilized for energy can be put to use. The proportion of hydropower enterprises in the segment Renewable energy sources amounts to 9 % represents 29 % of net sales, accounting for 19% of the employees. 44% of the hydropower firms have a foreign owner group (Stromberg, 2013).

Sweden in an international comparison

The following section presents data for a number of factors that influence the development of renewable energy: policy, investments and capacity expansion. The purpose is to establish an understanding of how Sweden stands in comparison with other neighboring countries. Money talks, below the per capita spending in the state budget divided in a number of environmental areas are presented. The figures are collected from the OECD.

Within the category of renewable energy there are numerous types of energy such as wind, solar and bioenergy. During most of the selected time period (1990-2014), the state finance invested in this sector has been limited. Denmark’s government was early to push their wind power industry to propel the industry’s development.

In 2013, the share of renewable energy in Sweden constituted 52 per cent of total electricity consumption. In Sweden, the most important renewable energy sources are bio and water power. A sector that contributes a great deal to Sweden's high proportion of renewable energy is the heating sector, where biomass and heat pumps have contributed considerably. The share of renewable energy in the transport sector in 2012 was 12.6 percent. Per capita, Sweden has maintained a higher level than most other EU countries when it comes founding in the state budget directed towards the renewable energy sector. However, the other Nordic countries maintained a higher level of investments in renewable energy, especially during the latter part of the reported time.

Energy Efficiency: Energy efficiency and energy saving is the attempt to streamline existing energy usage either by reducing energy consumption, or by getting more out of existing energy usage. In this manner society can use more energy in the without increasing energy production. Sweden has adopted the European Commission’s 2020 goal, with the aim of decreased energy consumption through energy efficiency by 20 percent compared with the baseline year 2008 (Energy Agency, 2014).

The Nordic countries spend relatively a lot of money in energy efficiency compared to the European . When it comes to energy efficiency, Finland has had a leading position - together with the other Nordic countries - during much of the period. In the near future, surpassing only Norway, Finland and Sweden. As the area of spending has not exceeded $5 per capita in Sweden for most of the period, Sweden is no giant when it comes to spending money in absolute terms.

The opportunities are not the problem

The Clean tech Group and WWF's (2014) rankings ranks Sweden as the country in the world where the general conditions for the taking up and pursuit of innovative start-ups are the best. The index looks beyond the traditional parameters of R&D, patents and academic publications to assess whether a country supports entrepreneurs. The index takes into account the attitudes entrepreneurship and cultural traits as key factor for entrepreneurial success. The Clean tech Group and WWF's note that the countries that perform best (Sweden, Switzerland on Canada and the US) have a climate where the contractor rarely need to be entrepreneurial in order to cope living expenses. Instead, the subject is rather a drive to create and the desire for freedom of work.

General innovation drivers	*Cleantech-specific innovation drivers*	*Evidence of emerging Cleantech innovation drivers*	*Evidence of commercialised Cleantech innovation*
1	17	4	9

As for state R&D support to various energy technologies, especially eco-energy, Sweden seems to be in the top. This is a general conclusion no matter what the research discipline you choose to study. Research efforts have not led to an equally significant business. Global Innovation Index is a measure of how well a country manages to turn research into market success. The index compares research efforts with outcomes from this in terms of new business and economic growth. Sweden ranks in the global top (number three in 2014) in research and development (Global Innovation Index, 2014).

During the Cleantech category-specific innovation drivers describe phenomena that give support to create greater market penetration and lower barriers to entry for businesses and industries. Both public support and private support is important here as well as access to industry clusters and to capital. In this field are Sweden very far down, behind countries like China and India.

Examples of countries that rank highest are Finland and Denmark. They are characterized by the largest public budget investment in clean tech seen the size of the economy, while they have a number of Cleantech clusters. There is also a vast financial and political support. They are also characterized by cooperation with other countries. These measures are considered to help firms and new technologies through the valley of death. Denmark and Finland have also managed to attract local investors to the market. France is ranked number three. In addition to a generous support system for firms, they have a long term policy to create incentives for investors.

Within the category *Evidence of emerging Cleantech innovation drivers* Sweden is in fourth place. Some countries have distinguished themselves in an interesting way category. One example is Korea whose patent office has a fast track for green innovations, which means that the time from submission to granted patents shortened considerably, down to a month in some cases. This is important in order to bring products to market. Sweden and the UK ranks among the countries with the most firms on the Global Cleantech 100 list of the one hundred leading private environmental firms in the world. In Sweden's case, attributed the success including Energy Agency's program to help with financing for firms in early stages of development.

The final category is commercialized Cleantech innovation, reflecting the country's ability to scale up innovations in Cleantech. It is measured with the manufacturing execution value added, corporate profits and the late private investment and number of listed Cleantech firms. Denmark is the leader with a production equivalent to three percent of GDP and the largest number of listed firms in relation to their economy.

A common explanation for Sweden's declining position in the innovation league is that the industrial structure is outdated. Many large Swedish firms based on technological breakthroughs that were made decades ago, certainly in profitable industries but with production capacity increases as one way to increase revenue.

Different types of countries - innovative, imitators and stagnant.

The main conclusion of the neoclassical economic growth model, Solow model, is that no long-term economic growth can be achieved without technological development. In the short term due to economic development in the accumulation of capital (Grossman and Helpman, 1993). A common assumption in the model is that the economy will always converge to an equilibrium rate of growth, which depends only on the technological development and to the labor force growth rate. In an international context, this means that a country's economic growth is not only determined by its own technical development but also of technical development abroad.

All countries will not grow at the same rate even if the new technology is theoretically free to all, after a certain time. Assuming that technological development comes from further development or imitation of other countries' technology realizes that development is neither easy nor free. A country's technology can be said to be dependent on its ability to invest in R&D as well as the country's capacity to absorb foreign technology. These occur through imitation, but not necessarily add anything to the existing global stock of knowledge

Stöllinger (2013) shows, by performing a series of tests on a data set consisting of 76 countries, the countries can be divided into innovative, imitators and stagnant countries. The group of countries that carry out innovations for which it is invested in R&D are moving the front line of the known knowledge in the world. Countries that imitates carry a limited amount of own research but they can absorb and use it as imported. The stationary group has insufficient human capital to absorb new technology. This leads to a large and growing technological gap.

The countries' economic growth is often negatively correlated with its output level (Barro, 1991). For example, China has grown by more than 7 percent per year for a long time has started to catch up with other countries' per capita level. Convergence theory has, however, assumed that capital in the classical sense as factories placed where there is the best return on them. Labor is cheaper and can do the same things, the production moved to those countries provided that the institutions are favorable (Maurseth, 2001).

Stöllinger (2013) argues that it cannot take for granted that countries that are technologically after will be able to catch up. Human capital will not behave as real capital. Silicon Valley is an area where wages as well as office rent is high; still choose technology firms to establish themselves there instead of Idaho, where wages are low and local costs minimal. To bring the technical development forward, firms invest in R&D. Others can then create innovations with the help of these advances.

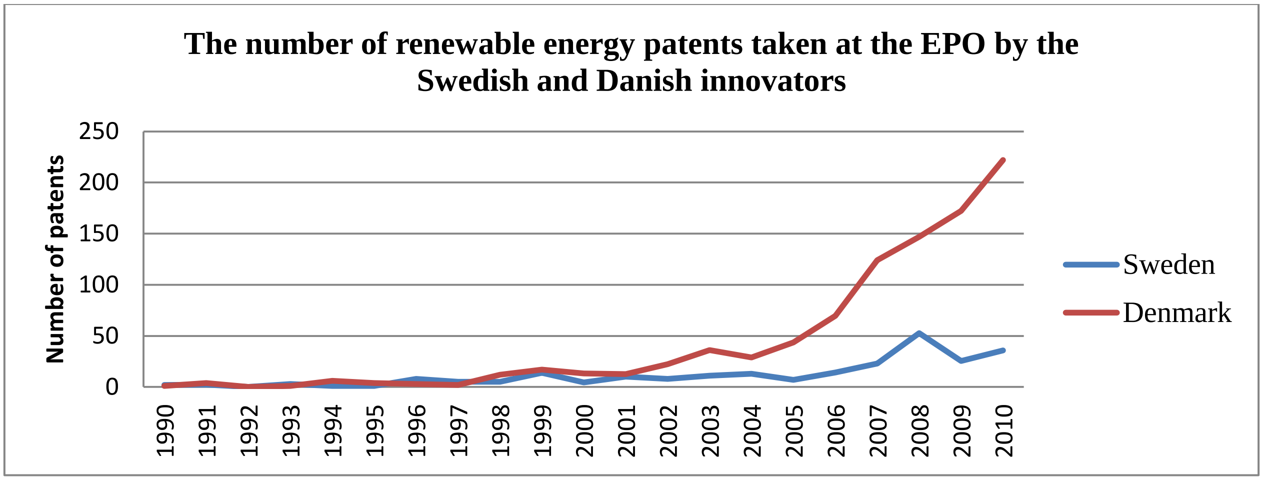


Figure 5. Data from the European Patent Office (EPO, 2014).

In a comparison with the European countries do not inventor from Sweden very often patents in the field of environmental energy at the EPO, the European Patent Office. Of course, the tradition of patenting differ from country to country and therefore the EPO interesting to get data from. It is more expensive to apply for patents at the

EPO, and complicated by a language barrier and the top management. Figure 5 shows the patent development of environmental energy patents over time in Denmark and Sweden. Until the 2000s, there were low in both countries. In the early 2000s, Denmark pulled off and is now above both the UK and France, which is illustrated in the graph below.

Adjusted for per capita figures are of course slightly different, but it did not change the fact that there is a significant difference between Denmark and Sweden - Swedish patent applications are few in environmental energy technology.

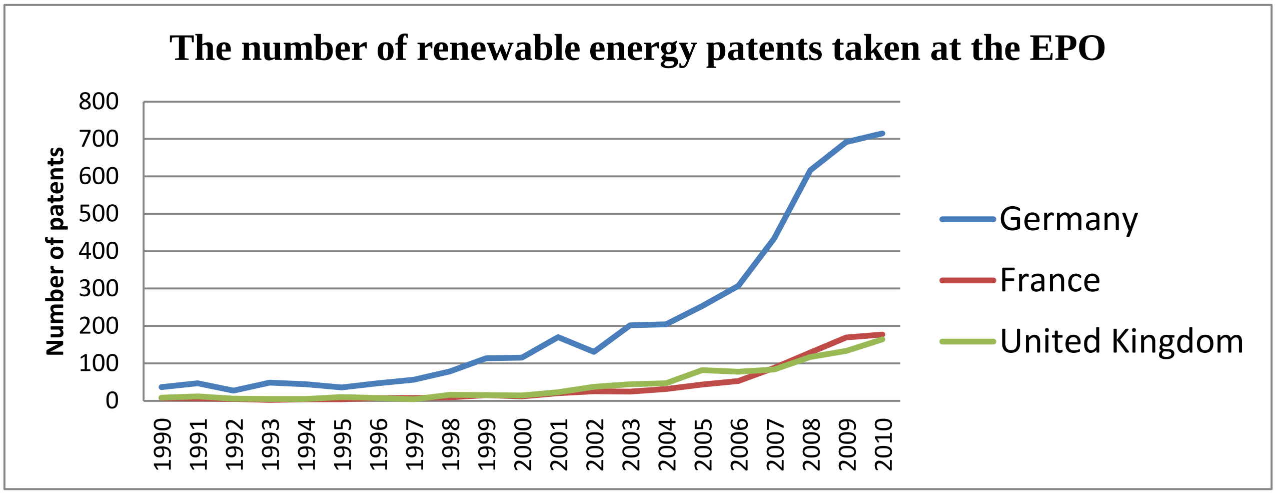


Figure 6.The number of renewable energy patents taken at the EPO. Data from the European Patent Office (EPO, 2014).

Although it is not possible to divide countries into similar categories Stöllinger (2013) made it seems to be the leader in the form of Germany and Denmark. Britain and France have a large number of patent applications which can be attributed to their overall size in terms of economy. Broken down by sector level we see that Swedish firms take patents primarily in wind and solar energy sector.

In the other renewable energy patent classes there is far less activity. Sea/wave energy and some geothermal energy have been developed in recent years. Regarding tides and ponds are not going operations in Sweden, which is not surprising when the tidal influence is marginal. Even within conventional hydropower patent level has been stagnant at a low level. The technology is mature, but it may be the case that the patent that improves the conventional hydropower can be taken in other fields, such as general improvements in structures.

Policy and capital availability

Especially new knowledge-intensive firms have big problems to finance its external growth, such as through bank loans (Smith, 2011). International statistics show strongly increasing venture capital investments in Cleantech / energy technology. Business Angels in this sector are relatively rare in Sweden. Based on industry-specific knowledge and networks, business angels tend to invest in their home industries. Therefore, they occur mainly in industries that during any period characterized by high yields (Laufer et al, 2013). This probably explains why there are relatively few in the energy industry.

In a study of Swedish business angels by Laufer et al. (2014) several angel investors expresses that they should not be taxed as hard as the risk of losses is high and the number of successful exit is relatively low. The private sector accounts for the lion's share of venture capital in Sweden. Privately owned venture capital firms represent 82.5 percent of the firms in Sweden, while state institutions represent about 11 percent and Group-owned enterprises 6.5 percent (Nyman, Lundgren and Rösiö, 2012). After the financial crisis, the total venture capital in Sweden decreased, while the political discussion on venture capital shifted.

Many times the investment goes beyond Sweden. One such example is the world-leading technology for the production of new cheaper thin-film solar cells developed by researchers in Uppsala and the Swedish spin-off company Solibro. When it was not possible to find capital in Sweden invested German Q-cells two billion in two production facilities in Germany. These two billion is close to the total annual amount of investment in the Cleantech area in Sweden.

Traditionally, those who worked with venture capital have been focused on a small number of industries, mainly in information and communications technology and biotechnology (Wüstenhagen and Teppo, 2006). A greater international interest could recently be seen for industries under the name of clean-tech globally and in Sweden (Usher, 2008). Experience from other industries has shown that different forms of risk capital can accelerate the market introduction of innovations (Kortum and Lerner, 2000). The share of venture capital goes to energy is still limited.

- Seed capital is the initial financing as an entrepreneur often needs to develop his idea and start his business. In this phase often add capitalist more knowledge and skills than capital. Typical Swedish seed investment varies from a few hundred thousand to several million. As this is a very risky form of investment, the state has supplemented the commercial operators with tax-funded institutions. It is also common for wealthy individuals, business angels invest in this phase.
- Growth capital is used when firms go from a relatively new business to a larger player. Typical investment size is 5-50 million.
- Bridge financing is a major investment of 50-250 million often used between growth capital and an IPO.

Cleantech sector, as mentioned earlier, no own field. Portfolio firms in many industries can be classified Cleantech firms. Below are the figures for the funding, public and private, which will Cleantech sector later (Tillväxtanalys, 2014). After the financial crisis lost a lot of private capital and it was not replaced by the rise in state funding. The trend has been similar in terms of capital in general to other sectors. The top of 4.8 billion reached in 2008, then decreased VC funds' investments in Swedish portfolio firms every year until 2012. In 2013, the trend was reversed and investment leveled off at 2.0 billion. Among public funds in 2013 was 68 percent of the investment volume to portfolio firms in the expansion phase. The corresponding share of the private funds was 49 percent (Growth Analysis, 2013).

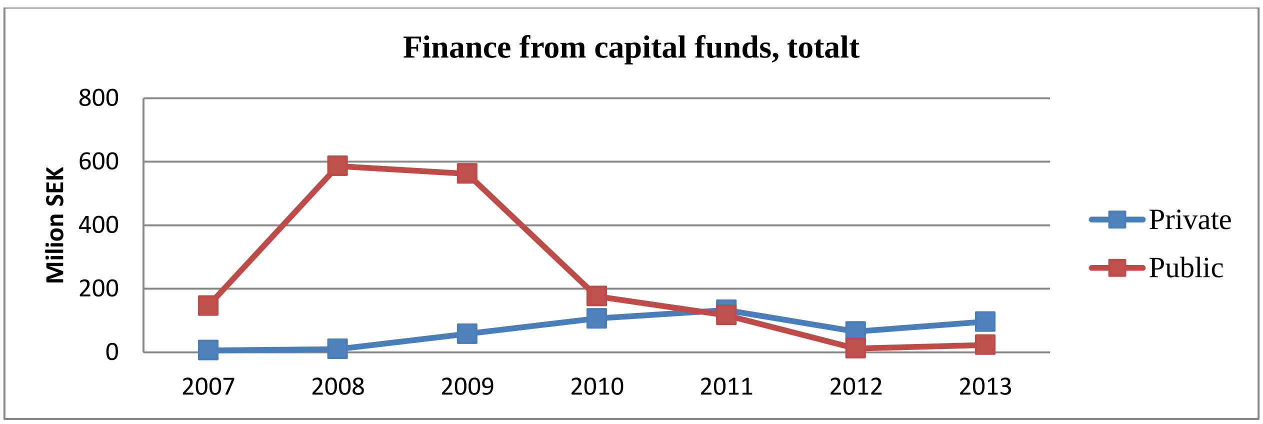


Figure 6 Privata och offentliga VC-fonders investeringar i Cleantechbolag 2007–2013, Tillväxtanalys 2014.

Public and private funds invested most money in the expansion phase in Cleantech. From the private investor's perspective, the behavior is reasonable. In the expansion phase is a finished product to be sold, and if the market reacts positively (something that should have been in the earlier launch phase); the Fund should be able to make money on the company. By contrast, to be in the seed stage or start-up phase is less likely actions of a private investor side.

From concept to finished product is a long time horizon. Half of the patent applications filed at the European Patent Office are rejected. Furthermore, a large proportion of patents granted are without economic value (Pakes, 1985;

Schankerman & Pakes, 1987). Of the patents registered, it has been calculated that the ten percent most valuable provide 48-93 percent of the total economic value for its owners (Scherer and Harhoff, 2000).

According to a study by the EPO, many smaller firms find the patent process difficult, therefore, they choose not to submit patent applications (Adams, 2005). In most industries, it is not a crucial problem to refrain from taking out a patent. There are methods of company secrets making patents unnecessary (Cohen, Nelson, & Walsh, 2000; Trajtenberg, 2001). In the area of environmental technology, however, patents necessary as it is possible to learn how many parts are produced by picking apart and rebuild, so-called reverse engineer,

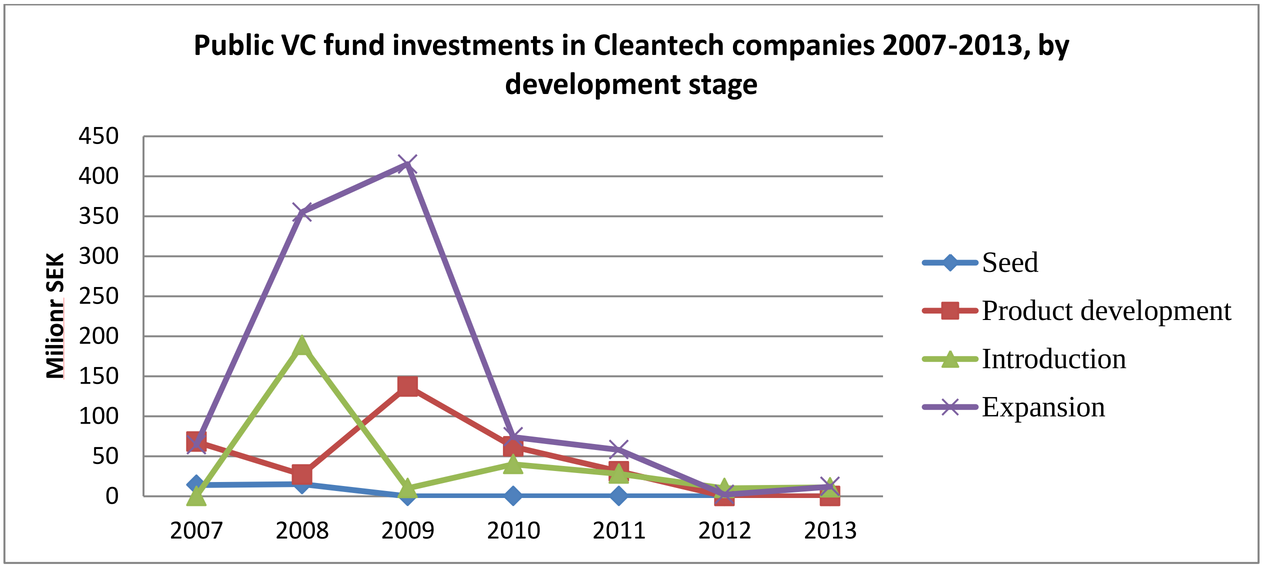


Figure 7 Public VC fund investments in Cleantech companies 2007-2013, by development stage, Tillväxtanalys (2014).

As for seed capital, there has not been a lot of money to get whether from public or private funds. Seed phase is not particularly resource intensive. It can be about a few hundred thousand or up to one million crowns to the entrepreneur should be able to set up his business.

Growth capital is used when firms go from a relatively new business to a larger player. Typical investment size is 5-50 million SEK in what can be considered the launch and expansion phase. At the end of the period, 2007-2013, such capital has been added, which may have helped to change the perception regarding the number of clean energy firms.

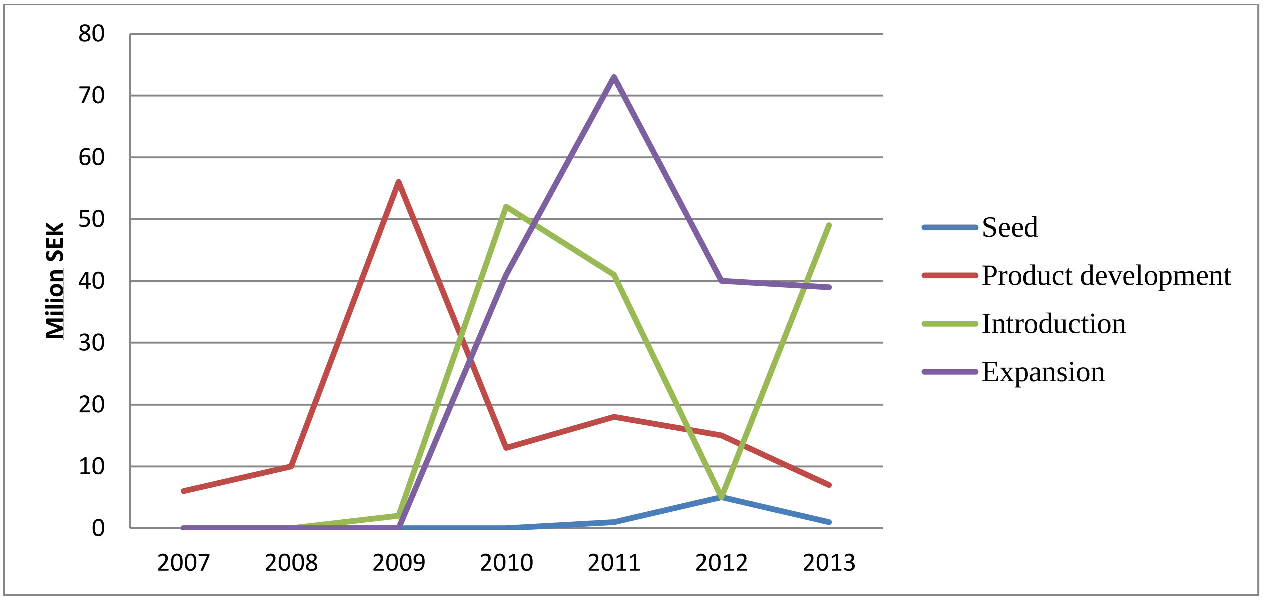


Figure 8 Private VC funds' investments in Cleantech companies 2007-2013, by development stage, Tillväxtanalys (2014).

Conclusions

Although Sweden is slightly behind the leading European countries in terms of wind and solar power is not necessarily an absolute disadvantage. One conclusion is that we know too little about the policy that those who assist with venture capital in Sweden want. Europe and North America also have different environments when it comes to state aid and implemented the policies. This is expected to affect respondents' answers. A policy that has been tried may be perceived as better than a policy not yet has experience.

As noted earlier, there are both advantages and disadvantages of being an early investor in a technology. The investing part build up a capacity to absorb new technology and make innovations in their field. However, one can be locked on a path that is not optimal when a major new innovation to be developed. For example, if the new material to solar power or new leafless design for wind becoming successful a big part of a previous investment in a technology that is rejected can be wasted, especially if you build a production rooster in the field.

The Swedish environmental technology sector has been analyzed on the basis of the three stages of technological invention, innovation and diffusion. The conclusion is that relatively few inventions and innovations made (though rising in recent years), the Swedish forces are spread in which a growing part of the energy mix is made up of energy from the sectors studied.

The paper also aimed to investigate in which of these phases, the Swedish environmental technology is strong, and where there are areas for improvement. A problem in the sector is that the number of firms is few and geographically dispersed. This means that people who have specialized in the sector, few employers, geographically, firms are also evenly spread across the country, which means that the cluster is not Bilas. There is also no natural employment areas where people can walk between the firms and thus cross-fertilize ideas. The formation of business clusters has been described as one reason why environmental firms are successful in Denmark.

The Swedish capital market for green energy firms is also too small. The number of business angels are also small, as the experience in the relatively new industry is limited and investors generally prefer to invest in sectors they know. A further observation is to get green jobs have grown. Investments in the sector thus have a negligible impact on the unemployment rate, which sometimes has been raised in connection with the development potential of green jobs sector, however, high turnover, which should be seen as positive.

Carefully drawn policy implications from this report is that the firms in the environmental energy industry cannot make the leap from small to medium size because there is a lack of capital for firms that want to grow. The geographical distribution weakens the chance of the emergence of a strong technology clusters with positive spillover effects. Thus, those who provide capital to the sector, in all cases, the tax-funded part, consider if the allocation of capital works to strengthen the industry.

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