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Eco-innovation, technological learning and sustainable development

Stimulating emerging sustainable energy technologies through policy learning

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Abstract
Policy learning is together with technological, organisational and institutional learning an integrated part of the learning economy. It implies that policy-making itself is a process of learning and that this process more and more takes learning and competence building in many parts of the economy into account. The paper discusses opportunities and conditions for applying policy lessons learned from the Danish wind energy success case to other emerging renewable technology areas like solar cells. Although the empirical basis is the specific Danish context, lessons learned are relevant in a broader policy context as well.

Keywords: Innovation, Renewable energy, Policy learning, Denmark

1. INTRODUCTION

The dominating fossil fuel energy regime makes it difficult for alternative energy technologies like biomass, hydrogen and solar energy to overcome the existing mix of economic, political, institutional and technological barriers to entry. A more proactive policy is necessary, if a timely transition to renewable energy systems is to be implemented (Kemp & Rotmans 2005, Jacobsson & Lauber 2006, Smith 2008). Let free, privatization and market mechanism will not be able to secure such transition and paradigm shift just as the existing fossil fuel and nuclear energy systems over time have been (and still are)

[1] An earlier version of this paper was presented at the Conference on *Joint Action on Climate Change*, Aalborg June 8-10, 2009.

heavily dependent on public investments in plants, infrastructure, research, etc, - not to mention the not included pollution effects of these energy regimes.

In this paper we argue that a policy learning approach is a constructive way to stimulate emerging sustainable energy technologies. We use the well-known Danish wind energy success as a reference case and discuss to what extent lessons learnt from this case can be applied to upcoming renewable energy technologies like solar cell energy.

Section 2 introduces the policy learning concept where policymaking is described, not as a means-ends, rational choice activity, but as a process of learning. In section 3 the Danish wind power case is used as reference case to illustrate key elements of a policy learning approach. In section 4 we discuss opportunities and conditions for applying policy lessons learned from the Danish wind energy case to an emerging renewable technology area as solar energy. Section 5 summarizes the main conclusions.

2. POLICY LEARNING

A policy learning perspective implies a shift away from the perception of policymaking as a rational decision making process in a means-ends context. It implies that policy-making itself is a process of learning. This is done partly as a conscious, and maybe even designed, process in which policy makers, bureaucrats, experts and scholars communicate and develop values, knowledge, competence and institutions over time – what we in the following refer to as *direct policy learning*. It is also done in a less conscious, learning by doing way, or even as learning by accident as when policy makers discover that environmental regulations also in some cases, unexpectedly, increase competitiveness – *indirect policy learning*.

Policy learning is to be understood in a broad sense. It ranges from small incremental changes in for example the composition of different energy taxes reflecting concrete experiences from praxis to more fundamental shifts in policy visions aiming at a fossil free national energy system.[2] Sabatier (1993) distinguishes between three types of policy learning:

- *Instrumental learning* refers to learning about policy instruments – that is how different policy instruments can be improved to achieve specific goals
- *Conceptual learning or problem learning* means a changed (new) outlook or understanding of a problem. This is often related to adoption of new concepts, principles and images (understanding).
- *Social learning implies c*hanged (new) shared values, norms, goals and framing of issues/perspectives.

Our application of the policy learning concept includes all three dimensions.

The concept of policy learning also implies a new perspective on a broad set of policies including social policy, labour market policy, education policy, industrial policy, energy policy, environmental policy and science and technology policy. These policies may be looked upon both as specific areas of policy learning and as activities affecting learning

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[2] Sabatier (1993, p.19) defines policy learning as ”a relatively enduring alteration of thought or behavioural intentions that are concerned with the attainment (or revision) of the precepts of a policy belief system.”

and innovation capabilities in many parts of the economy. Furthermore, policy learning calls for co-ordination across these policy areas.

Policy learning can take different forms (Gregersen & Johnson 1998, 2008, Edquist et al. 1998, Lundvall & Borrás 1999, 2005, Mytelka & Smith 2002).[3] However, based on innovation studies and the learning economy as an overall framework we argue that – at least - the following elements should be included in a dynamic innovation policy supporting sustainable development:

(a) Forming visions about the learning economy as an environment for innovation and sustainable development and forming the value premises of innovation policy.

(b) Developing a system of innovation approach to policy making including development of new concepts, data, and theories of innovation and systems of innovation.

(c) Establishing new practices and routines in the conduct of policies stimulating learning and innovation including gradually trying, testing, and evaluating new practices and routines.

(d) Stimulating regional and local experiments in policy areas in need of reform and developing new methods to evaluate the outcomes of such experiments that take into account learning effects.

(e) Institution building that supports the production and reproduction of human and social capital and diffusing international, regional and local 'good practices' in this field.

(f) Analyzing and comparing systemic features and critically important indicators in a form for benchmarking across regions, organizations and nations.

(g) Stimulating democratic participation in the design and implementation of innovation strategies including forms of ongoing dialogues between employees, unions, researchers and governments.

In the following we use these seven elements as point of departure for extracting policy lessons from the Danish wind power case in order to discuss their relevance for other renewable energy technologies. The argument requires an understanding of the complex co-evolution of technological, economic, institutional and political factors that shapes innovation.

3. MAIN POLICY LESSONS LEARNED FROM THE SUCCESS CASE OF DANISH WIND POWER

3.1 The Danish wind power case at a glance

The Danish wind power story is well described in several sources (see for instance Dannemand Andersen (1993), Karnøe (1995), Jørgensen & Karnøe (1995), Krohn (1999), Hvelplund (2000), Kamp et al. (2004), Szarka (2006), Lipp (2007)). However, the story is still highly relevant as illustration of a process of policy learning based on co-evolution of technological, economic, institutional and political factors.

[3] There are clear and increasing intellectual similarities to the so-called Transition Management approach mainly developed by a group of Dutch scholars and recently implemented by the Dutch Government (see for instance Kemp 1994, Kemp & Rotmans 2005, Geels & Kemp 2007, Meadowcroft 2007).

The production structure – from enthusiasts to world leaders

The strong anti nuclear power movement and the energy supply crises in the late 1970s spurred a growing interest in alternative sustainable energy technologies in Denmark. Most wind power projects in the 1970s began as private projects, where technically interested people made experiments with scaled-down versions (10-15 kW) of the Gedser machine (Karnøe 1995, Krohn 1999).[4]

When the more 'professional' turbine manufactures entered the scene in the late 1970s and beginning of the 1980s, they mainly came with a background in agricultural machinery (e.g. Vestas, Nordtank, Bonus, Nordex, and later Micon). One company, Wind World, was founded on gearbox and marine technology manufacturing (Krohn 2000).[5] The wind turbine companies are in that sense an illustrating example of how learning is cumulative and often based in the national production structure.

In the late 1970s there were about 20 Danish manufactures entering the wind turbine market, but the home market was still modest. In the beginning of the 1980s the State of California began a program of support to wind power development and the Danish producers benefited and learned a lot from this expansion. However, when the California wind program ended in 1985-86, a large number of the Danish manufactures went bankrupt or merged. The merger and acquisition process continued within the wind turbine manufactures and today the two companies, Vestas (merged with Micon) and Siemens Wind Power (acquired Bonus Energy in 2004) are the dominating 'Danish' players. In many ways the wind turbine industry has followed a traditional industrial maturity path with increasing industrial concentration and capital intensity, growing internationalization of ownership and finance, and increased importance of R&D and patents.

The period from 1987 to 1991 was weak both regarding the domestic and the export market, but since the 1990s the development is characterized by a steady increase in especially the export market. In 2006 exports accounted for 99 per cent of the sales, see Figure 1. The export from the Danish wind industry was in 2006 27 billion DKK and the wind industry employed more than 21.000 people in Denmark. In 2006 the Danish manufactures sold 5.439 MW power, roughly corresponding to 33 per cent of the global market. If turbine wings and other components are included, the Danish wind industry has a market share of 40 per cent on the global market (Danish Wind Industry Association, 2008).[6]

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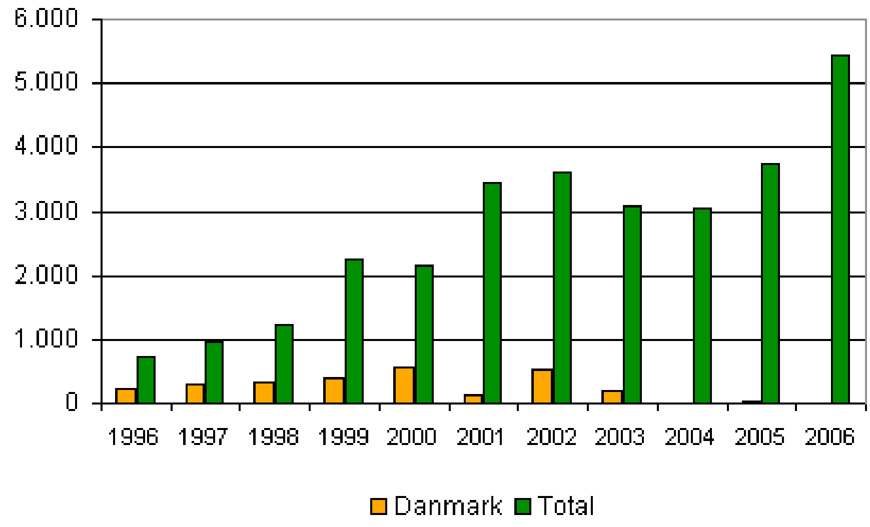
[4] The use of wind power for electricity generation is more than 100 years old and goes back to the 1890s, where the Danish meteorologist, inventor, and folk high school principal, Poul la Cour, started experiments converting classical windmills to electricity generation.

[5] While the Danish wind turbine manufactures, mainly had a background in agricultural machinery, the wind power companies in the US, Sweden, and Germany (e.g. Boeing, Lockheed, Westinghouse, MBB, and Siemens) had a strong background in aircraft and generator manufacturing.

[6] Up-scaling has been a major characteristics of the wind power production. The early machines produced 25 kW and had a 10.6 metre rotor diameter. Today's turbines produce 2-4 MW with 90 metre rotor diameter placed on 100-150 metre towers. More and more wind power capacity is produced in wind power parks and in the future more of these will be installed offshore.

Figure 1: Wind turbine sales (Danish manufactures) – MW (1996-2006).



Source: Danish Wind Industry Association (2008)

Energy policy and the demand pull effects

In the first Danish energy plan from 1976 wind power was planed to cover 4 per cent of the total Danish electricity consumption. In the second energy plan (Energy Plan 81) the wind power share was expected to increase to 8 per cent in year 2000. Today (2009) about 20 per cent of the Danish electricity production is covered by wind power. The latest Danish long term energy plan (Energy 2025) states that at least 30 per cent of the electricity production in 2025 should be produced by renewable energy sources with the largest part coming from wind power (especially offshore).[7] While the main arguments for increasing the wind power electricity share in the 1970s and the early 1980s were a question of finding alternatives to nuclear power and securing the energy supply, the wind power strategy today gives a significant role to the required CO_2 reduction.

A mixed palette of policy instruments has been introduced to stimulate the Danish wind power production, and we only mention a few here. The utility obligation to buy wind power at 85 per cent of the retail price level was crucial for the wide diffusion of wind energy. Another important measure was a 30 per cent subsidy of investments in new wind turbines. The investment subsidy was introduced in 1979, but was gradually reduced until it was abandoned ten years later.[8] As an integrated part of the early long term energy plans

[7] This is in fact a reduced ambition compared to the former energy plan (Energy 2001) aiming at 50 per cent of the energy consumption produced by a palette of different renewable energy sources in 2030. A more ambitious scenario developed by Megavind (a public-private partnership with key actors in the wind power sector) has suggested 50 per cent of the energy consumption supplied by wind power alone.

[8] During this period, more than 3000 cooperative wind turbines were installed. Typically, a cooperative wind turbine has between 20 and 40 owners. This means that around 1990, there were between 100,000 and 150,000 owners of wind turbines in Denmark (Hvelplund 2000).

was the mapping of potential wind power sites based on systematic wind analyses. Since 1985 the Danish government has ordered the utilities to install various amount of wind power and recently, relatively high green taxes on all electricity - but with a partial refund for renewable energy including wind power - has made wind power much more attractive for the power companies.

The regulation regime (feed-in tariffs), where buyers of wind turbines receive a fixed price from the electricity companies and a fixed public service payment for CO_2-free electricity production, has motivated the producers to lower their production prices, as they were in a situation where more wind turbines could be sold if the prices decreased (Hvelplund 2000).

Knowledge infrastructure, knowledge sharing, and interactive learning

It is not possible (or the intention) here to give a full description of the knowledge infrastructure that evolved in relation to the Danish Wind power Innovation System. Only a few key-players are mentioned below.

The establishment of the public wind power test station at Risø Research Laboratory in 1978 turned out to be crucial for the development of the Danish wind power activities in relation to the production, distribution, and regulation of wind power knowledge. To receive the public investment grants a wind turbine type approval from the national laboratory was required. This approval process was an important part of the knowledge development and diffusion both among and between the wind turbine manufactures and the investors, and thus stimulated an interactive learning process. The very strict safety and performance requirements put a persistent pressure on manufactures to upgrade their design and manufacturing skills, and today Risø DTU[9] is among the leading international research institutes on wind turbine technology and wind resource assessment.

Most wind turbine owners are organized in the Danish Wind Turbine Owners' Association that publishes a monthly magazine with production figures and notes on technical issues. The statistical database, user groups, and technical consulting services for members have been important instruments to secure a transparent market based on shared knowledge (Krohn 2000).[10]

The manufacturers of wind turbines have their own organization too – the Danish Wind Industry Association. The organization carries out an extensive information work, makes policy analyses, takes part in standardization activities, and is involved in national and international R&D-activities.[11]

In 2006 a new Public-Private Partnership, 'Megavind', was formed in order to formulate a coherent strategy for future innovation activities within wind power technologies. Members of the partnership network are key players within the wind industry, energy supply companies, universities, and the Danish Energy Agency.

It seems fair to conclude that knowledge sharing and interactive learning among key players have been (and to a certain extent still are) important characteristics of the Danish Wind Power Innovation System. At the beginning of the industrial development, an "open source strategy" seems to have prevailed for the benefit of the whole system, but it is an

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[9] In 2007 Risø merged with The Technical University of Denmark, DTU.

[10] See www.dkvind.dk for more information.

[11] See www.windpower.org for more information.

open question how today's tendencies towards patenting and other forms of knowledge protection may influence knowledge sharing and innovation activities in the future.

3.2 Main policy lessons learned from the Danish wind power case

Returning to the proposed seven basic ingredients in innovation policy learning, the following synthesizes major lessons learned from the Danish wind power case.

(a) Forming visions. The various national energy plans have been a key policy instrument to help forming and implementing a vision for a national energy supply system with a relatively high share of renewable energy – especially wind power.[12] But this top-down policy would never have been implemented had it not been for the range of local private and public actors and 'advocacy coalitions' pushing and lobbying for increasing production and consumption of renewable energy. The policy process can best be characterized as a combination of bottom-op, top-down processes (Hvelplund 2000).

(b) Developing a system of innovation approach. Since most innovations occur as results of interactive learning processes in complex systems, system building, maintaining and coordination are necessary policy tasks. One of the key factors for the success of the Danish wind power sector is the combination of energy and industrial policy right from the beginning.[13] In retrospect the policies may of course seem more coordinated than they actually were at the time, but the mutual interests and collaboration between domestic key actors within the innovation system have clearly paved the way for learning and capability building.

(c) Establishing new practices and routines in the conduct of policies stimulating learning and innovation. The Danish wind power case shows that synergy can be obtained by a strategic combination of different instruments (market and non-market based). Different policy interventions are required (and are effective) in different stages of the product cycle (see for instance Midttun and Gausten 2007). In the early innovative phase where the risk and uncertainty are high, R&D policies and subsidies in the form of feed-in tariffs are relevant. Later niche market policies as for instance quotas (certificate market) may provide further stimulation for commercialization of renewable energy.

(d) Stimulating regional and local experiments. From an evolutionary point of view creating room for variety is crucial for the innovative dynamics. Quite an amount of experimenting with wind power has been supported during the period and different forms of financial and technical support for test-mills has been tried. An interesting case is the small Danish island of Samsø with 4.000 inhabitants. In 1997 the Danish Energy Agency initiated a national competition between the smaller Danish islands where the winner would be expected to convert all its energy consumption to renewable energy within 10 years. Samsø won the competition and today the island is 100 per cent self-sufficient with wind-generated electricity. About 70 per cent of the heating needs of the island are met with renewable energy, and the transportation energy consumption is 100 per cent compensated by the electricity production from the offshore wind turbines.[14]

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[12] The exclusion of nuclear power from the overall Danish energy system paved the way for such alternative energy strategies.

[13] A similar holistic view on energy, environment, innovation and industrial policy is seen in Germany in relation to the fast growing solar energy sector spurred by a subsidized home market.

[14] For more information about this 'controlled experiment', see http://www.energiakademiet.dk

(e) Institution building. Institution building and institutional learning has all the way characterized the policy learning approach within the wind power case. The long-term energy plans, the establishing of the National Research Centre Risø and the various regulations and standards have been key formal institutions supporting learning and innovation. Of crucial importance for the knowledge generation and diffusion are the more informal institutions in the form of tight collaboration and extensive networking between the key actors in the Wind Power Innovation System, for instance the so-called Wind meetings, publication activities, industry associations, NGOs and various Public-Private Partnerships as the relatively new Megavind partnership. Such formal and informal institutions reduce uncertainty and shape the path of innovation.

(f) Analyzing and comparing systemic features. Systematic monitoring and benchmarking of different performance indicators related to wind power production and consumption has since the very beginning of the wind power growth been an integrated part of the technological, organizational, institutional and policy learning activities. At the national level the Wind Industry Association and the Danish Wind Turbine Owners' Association have both played a key role in institutionalizing the data collection and providing and publishing systematic analyses of the results.

(g) Stimulating democratic participation in the design and implementation of innovation strategies. In a way the whole area has been a testing ground for new forms of democratic participation in technical as well as policy development. Non-governmental organizations and publicly financed local energy offices as well as the traditional consumer owned electricity system have played important roles in the process. Compared to most other countries there has been a broad public acceptance of wind turbine installations around the Danish country and coast sites. The broad social acceptance of the many wind turbines in the landscape is clearly related to a participatory planning process combined with the economic incentives that the government policy has provided for the many wind power owners.[15] At the same time as there is a gradual, interactive process of policy learning in the Danish wind power system one can also identify a contradiction between its local and democratic aspects and the development of international electricity markets. The opening-up of the traditionally rather closed Danish systems threatens some of its interactive learning capabilities.

4. LEARNING FROM HINDSIGHT

4.1 Context matters

Context matters in policy-making. In that sense there are of course limitations to what extent it is possible to learn from hindsight. In addition, when one looks back on a historic process it is not always obvious what one can learn from it for future use: which were the defining moments and crucial events? History never repeats itself and policy-making must be an ongoing process of learning, even when it builds on hindsight. However, retrospect may improve policy learning and help to take the changing context onboard.

First, the liberalisation and internationalisation of the energy sector implies that the framework conditions for developing new energy technologies are quite different than when the wind energy industry took off 20-30 years back. Various private actors have entered the energy scene and a prevailing market oriented policy and regulation regime

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[15] Local participation and ownership is a key factor for the success of the Samsø project mentioned above.

implies that the creation and regulation of the energy markets in general is governed by more short-term economic rationalities.

Second, increasing globalisation implies that companies also within the energy industry (companies developing, producing and selling products and technologies for energy production) today experience more fierce international competition than many small and medium sized companies did 20 years back.

Third, knowledge creation and technology development is becoming more international. Danish companies, for instance, collaborate not only with domestic universities but increasingly also with foreign companies and research institutes, including setting up research centres outside their home country.

Fourth, the institutional setting for knowledge production and knowledge sharing has also changed due to an increasing focus on IPR in private companies and public universities.

Fifth, international policies in the form of EU regulations and international energy, climate and environment policies today play a much more important role as key drivers for the increasing demand for sustainable energy solutions today than 20 years back when energy policy primarily was a national (domestic) matter.

These and related factors mean that the conditions for developing new energy technologies have changed significantly since the wind energy 'adventure' started. Despite such changed framework conditions, we argue that important policy insights can be drawn from the Danish wind energy case in order to get a better understanding of what policy initiatives are necessary to stimulate innovation and business opportunities within currently new and emerging renewable energy areas. Seen from a policy perspective there are important similarities between the various renewable energy areas. Despite liberalisation processes, energy is still a highly regulated area, and regardless of growing importance of international policies national energy and innovation policies still matters a lot. New and emerging energy technologies all have to be integrated in an overall energy system and thus compete with prevailing oil and coal regimes. Supplementing the 'usual suspects' (firms, research organisations and government) in innovation system analysis, energy technology based innovation systems include a multifaceted group of actors as NGOs, energy companies with different ownership structure, and individual idealists investing and experimenting with different technological solutions. There are some new policy instruments (CO2 quotas for example) but the basic toolbox including administrative regulation and economic incentives are still intact.

In the following we use solar energy as an analogous example to wind energy, but in principle similar "exercises" can be made for biomass, hydrogen, wave energy, etc. - keeping in mind that the dynamics and conditions of innovation are sensitive to the specific technology areas as well as to the market conditions.

4.2. The Danish solar cell innovation system in embryo[16]

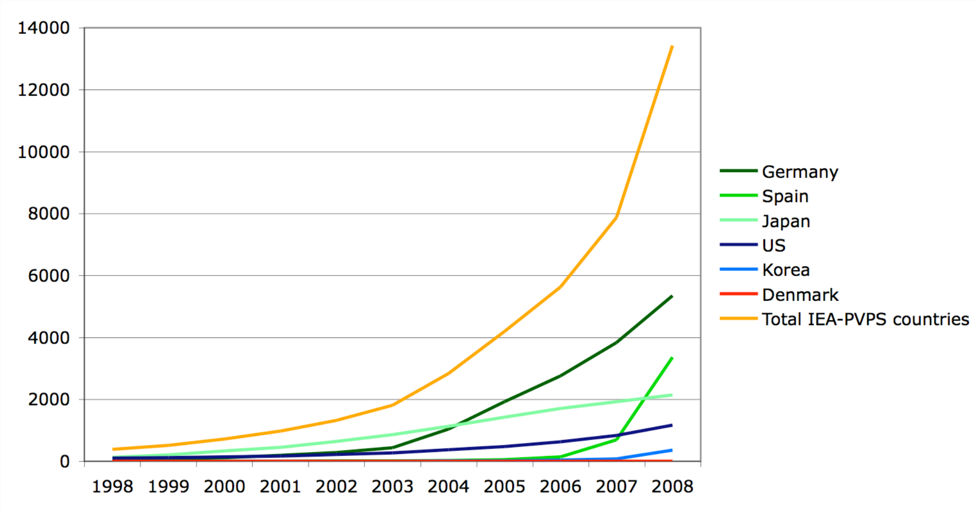
Solar energy technology includes thermal Solar Hot Water systems, Heating & Cooling, and electricity producing Photovoltaics (PV). Here we focus on the latter. The global potential for solar energy is very high. It is estimated that "about one hour sunshine on the surface of the earth corresponds to the present annual global energy consumption" (Ahm

[16] A more extended description (in Danish) is available in Borup, Dannemand Andersen, Gregersen & Nygaard Tanner (2009).

2007). The price per kWh solar energy is currently relatively high, but is expected to fall in the future and reach a competitive level within the next 8-10years.[17]

Solar energy is currently the fastest growing alternative sustainable energy source worldwide. According to the International Energy Agency (IEA) accumulated installed solar energy grew from 7.8 GW in 2007 to 13.4 GW in 2008 or in other words an increase equivalent to 71%. Germany, Spain, Japan and the US account for the majority, but recently, also countries as Italy, Portugal, Korea and China have increased their solar energy capacity substantially. While diffusion of solar energy has boomed internationally, no take off is experienced in Denmark yet. In 2008 the capacity in Denmark was 3.3 MW, in 2007 3.1 MW and 2.9 in 2006. Figure 2 shows the accumulated installed solar energy capacity in selected IES-PVPS countries including Denmark.[18] However, solar energy still contributes only with a very tiny share of the world energy production.

Figure 2: Accumulated installed solar energy (MW) in selected IEA-PVPS countries 1998-2008



Source: IEA-PVPS (2009)

Thus, while solar energy has been a high priority energy area in many countries, it is not given priority in the newest Danish national energy strategy (Energy Strategy 2025). Solar energy is included in the Danish public research funds, but only few resources have been allocated compared to for instance bio-energy, wind energy and fuel cells. However, inspired by the German success, optimists see solar energy develop into a new Danish industrial adventure like the Wind energy case. Others argue that the game is over and only a few potential niches are left for the Danish industry.

In a Danish context the solar cell innovation system is only in an emerging stage with relative few actors. The main potential area of application is Building Integrated PV systems (BIPV) and electricity grid connected systems. Currently, the Danish solar energy

[17] The learning curve for solar energy shows a learning rate of 20% meaning a cost reduction of 20% every time the energy production volume is doubled.

[18] IEA-PVPS: International Energy Agency Photovoltaic Power System program. 21 countries participate in the cooperation program.

industry has some strongholds within various niche products, for instance inverters, crystalline silicon for solar cells, BIPV elements and solar energy systems. Danish universities, research institutes and technological institutes are active within especially the so-called 3rd generation solar cells.[19]

No official statistics is available documenting the size of the Danish solar cell sector. Ahm (2009) estimates, that in 2008 the sector in total accounts for around 275 jobs (including research). In comparison, according to IEA, more than 28.000 solar cell related jobs existed in Germany in 2008, around 18.000 in Japan and 12.200 in Spain (IEA-PVPS 2009). The majority of the Danish production of solar energy related products are exported with Germany as the largest marked. DI Energy Section (Danish Energy Industry Association) estimates that the Danish export of solar cell related products has increased from around 10 mill DKK in 2001 to 275 mill DKK in 2007 (Ahm 2009).

With an estimated annual growth rate around 30-35% in global PV capacity until 2020 and an estimated investment exceeding 500 billion US$ the market potential is huge (Lorenz et al. 2008). The newest Chinese strategy to promote solar and wind energy will only push the development further.

As mentioned, Germany, Spain, Japan and the US are leading in the amount of installed PV, and the same countries host some of the world leading PV related industries. In short, the German solar cell case has many similarities to the Danish wind energy sector when it comes to support schemes for research, production and diffusion. An important home market has been created supported by feed-inn tax system, investment grants, and tax reductions combined with extended and targeted R&D programmes for developing solar cell technology. Table 1 clearly brings forward the message, that leading PV-countries have implemented a much broader pallet of different policy instruments in order to stimulate solar cell technology than Denmark.

[19] Within the 1st generation (Silicon-based crystalline cells) and 2nd generation (thin-film cells) Denmark has a relative weak international position. Within the 3rd generation (PhotoElectro-Chemical (PEC) and polymer solar cells there are some niche potentials for Danish research and industry.

Table 1: PV support mechanisms in selected countries

	Japan	Australia	US	Canada	Denmark	Austria	Switzer-land	Spain	Italy	Germany	United Kingdom
Enhanced feed-in tariffs		*	*	*		*	*	*	*	*	
Direct capital subsidies	*	*	*			*	*		*	*	*
Green electricity schemes	*	*	*	*		*	*	*	*	*	*
PV-specific green electricity schemes		*	*			*	*				
Renewable portfolio standards (RPS)	*	*	*								*
PV requirement in RPS			*								
Investment funds for PV			*	*				*		*	
Tax credit	*		*	*			*				*
Net metering		*	*	*	*	*	*		*		*
Net billing	*		*	*			*			*	*
Commercial bank activities	*	*	*							*	*
Electricity utility activities	*	*	*	*	*		*	*		*	*
Sustainable building requirements		*	*	*			*	*		*	*

Source: IEA-PVPS (2009)

4.3 Policy learning for stimulating an emerging solar cell innovation system

If the Danish society and Danish industry are to realize the energy and business potentials in solar energy it is necessary to initiate a much more proactive and direct policy learning process including:

(a) Forming visions. As mentioned above, solar energy is not currently prioritized in the Danish energy strategy (Energy Strategy 2025). However, a policy strategy with clear ambitious and concrete minimum goals for production and diffusion of solar energy is needed. Such a plan should also define the ultimate goals of a solar cell policy. The policy learning may aim at improving international competitiveness, economic growth, employment and other traditional economic policy goals. Alternatively it may aim at improving the environment or securing future access to energy. Probably all these goals matter, but it makes a difference if policy learning is perceived as economic policy, environmetal policy, energy policy or a specific combination of them. It will affect the agendas and the distribution of power and influence of the involved actors at different levels. A concrete strategy and long-term plan reduces uncertainty and risk related to the future state of solar energy in the Danish energy production, and thus guides the direction and stimulates private and public investments in developing future solar cell based solutions.

(b) Developing a system of innovation approach. A much stronger coordination of energy policy, innovation policy and industrial policy is necessary if a Danish solar energy innovation system is to evolve into an important player in the Danish energy system and

economy. Currently it is very small and scattered with only a few actors operating in a few niches.

(c) *Establishing new practices and routines in the conduct of policies stimulating learning and innovation.* The domestic application of solar cells in Denmark is very limited. Only very few private and public buildings have solar cells. In the 1990s and early 2000s a few development programmes (SOL-300, SOL-1000) were established in order to ensure strategic learning from application and experiments. The earlier solar energy programmes did initiate creation of new knowledge and innovation within specific areas – especially system design, modules, inverters, BIPV, and architecture. Currently no such programmes exist.

> "Apart from the R&D funding there is in practice little policy support and innovation-oriented regulation efforts. A net account system where owners of grid-connected household installations only pay tax for their net consumption of electricity from the grid, has only recently been established permanently – more than 10 years after the first grid connected installations. For larger installations, a feed-in tariff system ensures a minimum price for the produced electricity. This is however of little practical importance as the tariff is too small to make a significant difference in the economy of the installations. All in all, the need integration and innovative drive through support of market formation are currently very limited and stand completely in the shadow of the efforts in Germany and other countries. The recently renewed general building code increases the requirements to the energy performance of new buildings. This has led to new innovative activities by architects, amongst them integration of solar cells in some cases." (Borup et al. 2008)

Special - yet unfolded - opportunities for stimulating learning and innovation is using public technological procurement as a much more active policy tool. For instance if stronger regulations and economic incentives to make experiments with solar cell technologies was demanded in connection to new public buildings (offices and institutions) and renovation of existing (roofs, windows, walls, etc.). Such policy could generate more domestic full-scale demonstration projects and develop "show cases" for potential export concurrently with reduced energy consumption.[20]

(d) Stimulating regional and local experiments. Room for variety is crucial for innovation, but today only few local experiments with different technological solutions take place compared to for instance Germany, Japan, and US. A few exceptions exist – for instance initiated by EnergiMidt (consumer owned energy company), a couple of Danish municipalities (e.g. Copenhagen, Herning, Tønder), and Nordic Folkecenter for Renewable Energy. Public programmes opening up for local experiments with different solutions combined with knowledge sharing between users, producers and researchers are needed. It is furthermore important that such programmes have an adequate timeframe and not implemented as stop-go policy.

(e) Institution building. Recently (2008), the Danish PV sector has joint forces in 'Danish Solar Cell Association' in order to improve the framework conditions for solar cell research, production and diffusion in Denmark. The vision of the association is that solar cells should count for 5 % of the total Danish energy consumption in 2020. Creation of such formal and informal forums and networks for knowledge sharing (and lobbying) is decisive for learning and innovation. Based on the experiences from the wind power

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[20] In a very recent public funded 'renovation package' for private houses such opportunities are not fully 'cashed in'. The public support is primarily spent in order to increase short-term employment in the construction sector with only small side effects on the energy technology innovation and consumption.

sector, institutions supporting a broader interaction between solar cell producers and public and private 'consumers' should be established as well. Today, only few educational programmes incorporate solar energy as an issue. It is thus necessary to strengthen education (on all levels) within solar cell issues. It is also important that institution building within the solar cell doesn't conflict with similar efforts in related sustainable energy areas. Rather institution building, which leads to combined efforts would be preferable.

(f) Analyzing and comparing systemic features. International (not least German) benchmarking initiatives of various solar cell products, systems and techniques already exists and support for connected Danish initiatives would clearly stimulate diffusion of solar cells in a Danish setting as well.

(g) Stimulating democratic participation in the design and implementation of innovation strategies. According to Eurobarometer (2007) 95% of the Danish population is in favour of solar energy although only very few actually have solar cell energy as part of their energy consumption. Within renewable energy including solar energy NGOs play an important role for providing information and initiating debates and local experiments with solar energy.

Summing up, a broad mix of demand-pull and technology-push policies is necessary, *if* solar energy should develop into a 'serious' contributor to Danish energy production and at the same time generate future business opportunities for Danish companies.

5. CONCLUSION

The high degree of diversity between different energy technology areas implies that an effectual innovation and energy policy has to take into account these differences. The policy has to reflect the variation in maturity of both markets and technology. In areas like solar cells, where the Danish market is still emerging, qualified demand – for instance in the form of strategic public procurement - is central for the technology to develop further. In other words, new emerging energy technologies and energy systems as for instance solar energy requires public support stimulating both the supply and demand side in order to be competitive with established fossil fuel technologies.

Continued innovation requires variety with room for experimentation and evaluation of alternative solutions to technological, organizational, institutional problems. Creating and utilizing such 'interactive learning spaces' (Arocena and Sutz, 2000) is driven by a combination of innovative framework conditions at the system level and entrepreneurial 'fiery souls' at the individual level.

Maintaining a long-term, pro-active policy with specific and ambitious targets for implementing renewable energy systems is essential. Development of new energy technologies takes place in a context of high technological and market uncertainty. Such uncertainty can be reduced by a long-term combination of a visionary innovation and energy policy. Stop-and-go finance of for instance R&D projects, demonstrations projects and subsidies are often contra-productive.

In the Danish public policy debate, the Danish wind energy 'adventure' has often been highlighted as a success case to follow for other industries. However, the fact, that the Danish wind energy success reflects a long-time co-evolution of technological, economic, political, and institutional elements, makes it a complex matter to draw clear-cut lessons and apply these to other areas. A policy learning approach may be a helpful tool as a starting point.

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