Danish and Dutch wind energy policy 1970–2000: lessons for the future

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Abstract: Both in the Netherlands and in Denmark, policies to develop a wind turbine industry and to install a large wind turbine capacity were started in the 1970s. However, the outcomes of these policies were very different. A flourishing wind turbine industry developed in Denmark, whereas in the Netherlands, a few companies started building wind turbines in the 1980s and 1990s, but presently no wind turbine producers exist. How can this difference be explained? A number of factors can be pinpointed. The main factors are the following: Firstly, different technological choices were made. Secondly, different policies were introduced for wind turbine owners in both countries. Thirdly, the opinion of the utilities regarding wind energy in both countries was very different. Nowadays, both countries are focusing on offshore wind energy. The policy measures that are introduced and the technical choices that are made are path dependent. In other words, they follow from the policy measures and the technical choices in the past. How can the mistakes that were made in the past be avoided and what lessons can be learned for the future? We will elaborate on that in this paper.

Keywords: sustainable technology development; wind energy technology; renewable energy; system innovations; technological learning processes; wind energy policy; wind turbines; technology development, learning.

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Biographical notes: Linda Manon Kamp graduated in Technology and Policy from Utrecht University in 1996, where she also completed a Masters thesis on the system-dynamic modelling of sustainable land use. Subsequently she completed her PhD thesis on the development of wind energy in the Netherlands and Denmark, also from Utrecht University, in 2002. Her thesis focuses on innovation systems and technological learning processes. In October 2003, she joined the Technology Assessment group at Delft University of Technology where she is teaching courses on sustainable technology development and technology assessment. Furthermore, she is continuing her research into the development of wind energy and other energy sources.

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1 Introduction

Several Western countries started to develop renewable energy in the 1970s. The reasons were the oil crisis and the Club of Rome report, which warned of imminent shortages of traditional energy sources like oil and gas. The renewable energy source that people had the highest expectations of was wind energy. Two of the countries that were involved in the development of wind energy were the Netherlands and Denmark. Both governments gave active support to this development. Furthermore, both countries have a comparable wind regime. However, the result of the development of wind energy in each country is very different. In the year 2000, Denmark had a flourishing wind turbine industry that produced wind turbines for the world market. Furthermore, at the end of the year 2000 the cumulative installed capacity of wind turbines in Denmark was 2,340 MW and wind turbines produced 15% of the electricity demand. In the Netherlands, the situation was less rosy. Although 10–15 wind turbine manufacturers were active on the Dutch market at the beginning of the 1980s, in the year 2000 only one remained. Furthermore, at the end of the year 2000 only 442 MW of wind turbines had been installed in the Netherlands, though the target for the year was 2,000 MW.

What are the reasons for this difference in performance? Often, sitting problems in the Netherlands are mentioned as the reason why the Netherlands are lagging behind in the realisation of wind turbine capacity. However, our research shows that the Netherlands were already lagging behind in the 1980s, when the sitting problems were not prominent yet. Therefore, we looked for other reasons to explain the difference in performance.

Our focus was on learning processes during the development of wind turbine technology in both countries. Which directions were taken in the technological learning process? Which technological choices were made? Which actors were involved in the learning processes? Were they only technology developers and scientists, or also the users of the technology? And did interactive learning, or in other words, knowledge transfer between actors, take place? And if so, to what extent did it take place and between which actors? In the following paragraphs, we will describe the case studies with a focus on these research questions. After that, conclusions will be drawn on what can be learned for future renewable energy policies.

2 Wind turbine development in the Netherlands

In the Netherlands, two different developments can be discarded. Firstly, the government driven development of large wind turbines. Secondly, the more bottom-up development of small wind turbines. From the 1970s until the beginning of the 1990s, these two developments coexisted. They will be described separately.

2.1 The development of large wind turbines

This development was driven by the National Research Programmes on Wind Energy, the first of which was started in 1976. The goal of this programme was to develop a significant wind turbine capacity in the Netherlands, consisting of a large number of large wind turbines (BEOP, 1981). In the beginning, a large amount of theoretical knowledge on wind and wind turbines was gained at universities like Delft University of Technology

and Eindhoven University of Technology and at research centres like ECN. This knowledge was merely based on aerodynamic knowledge from the aerospace industry.

In the beginning of the 1980s, this knowledge was applied to the actual development of wind turbines. Three prototypes and four commercial wind turbines were built. The three main companies that were involved were the airplane company Fokker, the machine building company Stork and the electrical gear company Holec. Furthermore, the ECN research institute was involved in the project. The prototypes that were built were two Vertical Axis Wind Turbines (VATs) and one Horizontal Axis Wind Turbine (HAT). Large R&D subsidies were provided by the government to stimulate the development of wind turbines and to set up test programmes, in order to compare the VAT and the HAT wind turbine types. The main goals of the test programmes were obtaining measurement results regarding for instance the loads on the blades and the electrical power that was produced, and gaining operational experience (Sens, 1981). Especially the HAT prototype was very advanced. It could be operated with four regulating procedures. In this way, the regulating systems could be compared.

Because the first measurement results of the HAT prototype were satisfactory, Stork decided to develop a commercial turbine on the basis of the prototype. This commercial turbine was, like the prototype, a 300 kW turbine, which was very large at that time. Of the commercial turbines, called the Newecs-25, three were sold to utilities in the Netherlands and Curacao. At the same time, a 1 MW commercial turbine was also built and sold to a Dutch utility. This turbine was meant to be in between the 300 kW prototype and a turbine of 3 MW, which had been calculated to be the most cost effective wind turbine.

Soon, the problems started. The commercial turbines had not been tested extensively and had been designed in a far less sturdy way than the HAT prototype. Furthermore, the characteristics of the 1 MW turbine were different than those of the 300 kW prototype. Therefore unforeseen operational problems occurred like gear overheating and cracks in the blades, one blade even breaking off completely. In spite of the problems, the Dutch government kept on pushing the development of large wind turbines. The Ministry of Economic Affairs and SEP (the Cooperation Electricity Producing Companies), together developed the Sexbierum pilot wind power station. This wind power station consisted of 12 HAT wind turbines of 300 kW. During the design and building of the wind turbines, a lot of problems arose, which resulted in a long delay of the project. Also, when the power station came into operation, a lot of problems with a.o. turbine gears and blades occurred. Because of the many technical problems, the large financial risks and the small home market, in the mid 1980s all large Dutch companies stopped their involvement in wind turbine production. This meant the end of this wind turbine development path.

2.2 The development of small wind turbines

At the same time, about ten small companies were engaged in the development of small wind turbines (varying from 30 kW and 10 kW). They became involved in this field because R&D subsidies were made available, as from 1976, for the development of wind turbines. Although the Dutch government preferred the development of large wind turbines, companies that developed small turbines could apply for these subsidies as well. In contrast with the development of large wind turbines, the small wind turbines were developed on the basis of learning by doing, and trial and error, instead of theoretical

research and aerodynamic models. The turbines were sold in the vicinity of the manufacturers and therefore, problems could be solved quickly and the manufacturers could learn from them. In this way, knowledge was transferred between turbine users and turbine producers. The wind turbines were gradually improved and scaled up. Another place to learn from operational problems was the wind turbine test field at the research centre ECN. This test field was set up in 1981 (Stam et al., 1983). Here, general knowledge was exchanged between ECN and the manufacturers. ECN was forbidden to give the manufacturers direct instructions on how to improve their turbines, out of fear of distortion of competition. Between the manufacturers no knowledge transfer occurred, because they were rather hostile towards each other.

Another problem that the small turbine manufacturers encountered was the small size of the Dutch market. As written above, R&D subsidies were available as from 1976, but market subsidies were not made available before 1986. Therefore, payback times of wind turbines were large as were financial risks for wind turbine buyers (Werkgroep Duurzaam Energieplan, 1984). Furthermore, the wind turbine owners, who were not united in a group received only small payback tariffs from the utilities for the electricity that they delivered to the grid (Langenbach, 2000).

Gradually, the small wind turbines became better and larger. However, this process proceeded slower than in Denmark. This resulted in a backlag for the Dutch manufacturers on the large market in California that arose in the early 1980s. From the mid 1980s, when the large Dutch companies ceased their activities in the wind turbine field, the Dutch government became involved actively in the activities of the small wind turbine manufacturers. These manufacturers were now regarded as responsible for the development of a large wind power capacity in the Netherlands. Therefore, according to the Dutch government and the research institutes, the wind turbines which these manufacturers produced had to become larger and more cost effective, quickly. Firstly, market subsidies were introduced. This helped the Dutch home market grow to some extent, because utilities also started to show more interest in wind turbines. Secondly, according to the new governmental National Programme on Wind Energy, the research institutes and universities could only receive R&D subsidies if they made their research results applicable to the small turbine manufacturers. Researchers started to work together with small wind turbine manufacturers to scale up and improve their turbines. However, this cooperation appeared to be difficult, since the approaches and paradigms that were used by the researchers and manufacturers were very different: research driven technology development as opposed to learning by doing. The drive towards fast upscaling and the problems involved with incorporated advanced concepts and components in their wind turbines, combined with the small Dutch home market and the competition from the better Danish wind turbines on the Dutch market, resulted in severe difficulties for the Dutch manufacturers in the 1990s. By the year 2000, only one Dutch manufacturer remained.

2.3 Conclusions on the Dutch case

Now, let us look at the research questions posed in the introduction. Which directions were taken in the technological learning process? Which technological choices were made? Which actors were involved in the learning processes? Were they only technology developers and scientists, or also the users of the technology? And did interactive

learning, or, in other words, knowledge transfer between actors, take place? And if so, to what extent did it take place and between which actors?

In the development of large wind turbines, the focus was on the fast development of a large number of large wind turbines, based on advanced scientific concepts. The main actors involved were the Dutch universities of technology, the research centre ECN and the large turbine manufacturing companies Fokker and Stork. The users of the turbines were utilities. Interactive learning between the companies and the researchers went very well, because they shared the same paradigm of research driven technology development. However, hardly any interactive learning with the turbine users, the utilities occurred. Firstly, because the market was very small (only four turbines sold), and secondly, because the utilities had a very negative opinion regarding wind energy. They preferred large scale power plants fired by gas or nuclear energy and had little trust in wind turbines. After the many operational problems occurred, they became more and more reluctant to cooperate in knowledge exchange. This resulted in the development of scientific papers and models, but not in the development of wind turbines that worked well. It turned out that the fast upscaling of wind turbines was more difficult than was foreseen.

In the development of small wind turbines, the focus was on the gradual upscaling of small wind turbines, based on learning by doing and trial and error. The main actors were small manufacturing companies and the owners of the wind turbines. Also ECN was involved via the test field. Interactive learning occurred between turbine manufacturers and owners, which resulted in fast problem solving and the gradual improvement and scaling up of the wind turbines. Also with ECN, interactive learning took place on the test field. However, this remained limited to the transfer of general knowledge.

3 Wind turbine development in Denmark

In Denmark, as in the Netherlands, a wind turbine development programme was set up in the mid 1970s. Furthermore, as in the Netherlands, two development paths coexisted from the 1970s until the mid 1980s: the development of large wind turbines and the development of small wind turbines. We will not go into the case study descriptions in detail here. For these descriptions, see Kamp (2002, 2004) and Kamp et al. (2004). In this paper, we will only mention the main features of the Danish developments.

3.1 The development of large wind turbines

From 1977 until the mid 1980s, ten large wind turbines were built. The actors involved were the Danish Technical University, the Risoe research centre, two large Danish utilities and Danish Wind Technology. This wind turbine manufacturing company was especially established by the Danish Ministry of Energy and the utility SEAS. So in Denmark, the utilities were more involved than in the Netherlands. This network of actors developed and built wind turbines on the basis of the Gedser wind turbine, which had been built in the 1950s and had proved to work. Other inputs for wind turbine development were scientific theories and measurements. So, as in the Netherlands, this development was science based. Also, as in the Netherlands, many problems occurred with the large wind turbines, especially with the blades and gearboxes. In the mid 1980s,

the Danish government sold its shares in Danish Wind Technology. Building science based large wind turbines proved to be more risky and expensive than expected.

3.2 The development of small wind turbines

In Denmark, as in the Netherlands, in the 1970s, about ten small wind turbine manufacturing companies developed, relatively independent of the wind turbine development programme. The design philosophy of these companies was to build wind turbines that were reliable and safe, based on trial and error and rules of thumb. Trial and error learning was based on their own experience and on the experience of the wind turbine owners. Many more owners existed in Denmark than in the Netherlands, since in Denmark the market was subsidised. Furthermore, the wind turbine owners had joined the Danish Windmill Owners Association. This association disclosed the performance of several types of wind turbines in their magazine *Naturlig Energi*, thereby forcing the manufacturers to work hard on their improvement.

Another forum for knowledge exchanged was the so called Wind Meetings. These meetings were organised by the Risoe research centre. Their goal was knowledge exchange between turbine manufacturers, owners and researchers. Whereas the Dutch researchers tried to give the Dutch manufacturers knowledge on hightech concepts and models, the Danish researchers helped the Danish manufacturers to solve their practical problems. From the beginning, Risoe was dependent on the manufacturers for its financing. Therefore, Risoe's goal was not the development of the best cost efficient wind turbine, but the development of a wind turbine industry (Dannemand Andersen, 1993). The Wind Meetings also were a forum for knowledge exchange between wind turbine manufacturers. Because they all followed the technological guidepost of the Gedser wind turbine, they produced the same wind turbine type and encountered roughly the same kind of problems.

The large Danish home market, as a result of market subsidies, gave the Danish manufacturers the opportunity to produce a lot of turbines and learn by doing. Through these learning processes, the manufacturers were able to scale up their wind turbines at a faster pace than the Dutch manufactures and also to improve them at a faster pace. That gave the Danes a headstart on the large Californian market in the early 1980s. It also gave them a headstart on the European market. Presently, the Danish wind industry is still one of the leading wind industries.

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In the development of large wind turbines, as in the Netherlands, the focus was on large, science based technology development. The network of actors involved was more complete, which resulted in more knowledge exchange between turbine users and producers than in the Netherlands. However, the large costs and technical problems made this development come to a halt in the mid 1980s.

However, the development of small wind turbines was very successful in Denmark. Market subsidies helped to develop a large group of users. Therefore, many turbines could be produced and a lot of knowledge was transferred between the turbine producers and users. Furthermore, the paradigm at the Risoe research centre was more hands on than science based, especially in the 1980s. This made knowledge transfer between Risoe and the other actors very effective. Gradually, this tight network of actors succeeded in building up a strong knowledge base and industry, one of the leading wind industries in the world.

4 General conclusions: what can be learned for the future?

Which conclusions can be drawn from this historic case study for the future, especially for policies on renewable energy sources?

Firstly, we can conclude that building up a strong home market is very important. So, setting up policies to stimulate the development of renewable energy sources should at least include the stimulation of market development. The best way to do this is to subsidise per kWh of production. This will stimulate technology developers to develop cost effective technology. The existence of a strong home market is important for two reasons. Firstly, it will enable technology producers to sell more. Secondly, it will promote knowledge exchange between owners and producers. This knowledge exchange will be more successful if the owners are organised, as in the case of the Danish small wind turbines.

Secondly, we see that often technology is developed without taking into consideration the wishes of (future) owners. This was, for example, the case in the development of the Dutch and Danish large wind turbines. These turbines were developed, based on scientific theories and models, without looking at who the owners were going to be and what they wanted. In the Netherlands, the owners of the large turbines were expected to be the utilities, who were not enthusiastic about wind energy at all. The technology was more or less forced upon them. This hindered knowledge exchange to a great extent. Another example is the development of photovoltaic solar panels, which is also very much science based. The wishes of actors like designers of buildings and future owners are not taken into consideration at all. Changing this would result, in our view, in a larger market.

Thirdly, the case of the large wind turbine development shows that developing large machines in a constantly changing environment (different wind speeds), is difficult and risky. Therefore, thorough testing and taking small technological steps is important. The way the Dutch manufacturing company Stork underestimated the jump from a 300 kW to a 1 MW wind turbine was the reason for a lot of the problems with the 1 MW turbine. Therefore, in our view, designing offshore wind turbines with a lot of new science based concepts for deep water, is very risky. However, this is just what the Dutch development programme on offshore wind energy is striving for. In our view, taking smaller steps from shallow to deep water and from proven technology to new concepts would greatly reduce the risks. And, since wind energy is not popular in the eyes of the general public, because of the so called Not In My BackYard problem, it is important that the Dutch development programme succeeds in developing good, reliable turbines and does not turn into a failure.

Fourthly, the case of the Danish development of small wind turbines shows that building up a strong network and involving several kinds of actors is important. Because in Denmark, the wind turbines were often owned by a whole village or large parts of a village, the sitting problems were less severe than in the Netherlands. The villagers had both the advantages and the disadvantages of the wind turbines. The same is true for the sitting policy. It is important to involve policy makers at all levels, local, regional and national. In the Netherlands, local policy makers were not involved in the wind turbine sitting programme of 1991, which resulted in a lot of opposition from the municipal councils.

And, finally, formulating a long term consistent policy is important. Since, as it appeared from the cases, developing wind turbines is expensive and risky, it is important that financiers can be sure of the subsidising schemes remaining unchanged for the coming years. Recently, we saw that both in Denmark and in the Netherlands, subsidising schemes were stopped. This poses a great threat for the further development of wind turbines.

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