Paper presented at International Energy Workshop, June 24-26, 2003
IIASA, Laxenburg, Austria

DRAFT - PLEASE DO NOT QUOTE OR DISTRIBUTE WITHOUT PERMISSION

Wind power in Finland up to the year 2025

Vilja Varho [a], **Petri Tapio** [b]

[a] Department of Limnology and Environmental Protection, P.O.Box 27, FIN-00014 University of Helsinki, Finland, phone: +358-9-19158839, fax: +358-9-19158462, e-mail: vilja.varho@helsinki.fi
[b] Finland Futures Research Centre, Rehtorinpellonkatu 3, Fin-20500 Turku, Finland
phone: +358-40-5552963, e-mail: petri.tapio@tukkk.fi; http://www.tukkk.fi/tutu/engltapio.htm

Abstract: *In this article we present scenarios of wind power development in Finland up to the year 2025. We asked 14 experts to describe probable and preferable futures, through the means of a questionnaire and interviews. The 28 cases were grouped using cluster analysis, and the emerging five clusters were complemented into scenarios by qualitative analysis of the interviews. Wind power production grows in all scenarios but there were differences in the order of magnitude of ten The growth rate of electricity consumption slows down in all scenarios. The main emphasis in the analysis was on qualitative arguments which varied even within clusters. Wind power policy emerged as the main dividing factor.*

1 Introduction

The growth of cumulative wind power capacity in the world has been staggering, 26 to 37 percent yearly in 1996-2001 [1] (Fig.1). The growth has been accompanied by rapid technological development [2]. Simultaneously, the costs of wind power have decreased[1].

This global growth has inspired both Finnish industries which produce components and materials for the wind turbines, and the Finnish policy makers who see wind power as one potential source of renewable, emission-free electricity. So far the growth of domestic capacity has been quite slow, leaving Finland in the unique position where the current domestic wind power capacity is less than 50 megawatts (MW), providing only 0.1 % of electricity consumption, but there is considerable wind power industry, with export value of some 200 million euros in 2002. In other words, Finnish wind power components have a global market share of approximately 5 percent, when the installed capacity in Finland is only about 0.2 percent of the global capacity [4]. The novelty and marginality of wind power in

[1] The costs of technologies can often be seen to decline by a steady percentage (= learning rate) over each doubling of cumulative sales. A wide variety of learning rates have been found for wind power, ranging from 4 to 32 percent [3].

Finland are an asset for this study: Finnish wind power is a sufficiently clearly definable issue, and it is currently of limited importance but has a great potential for growth and change.

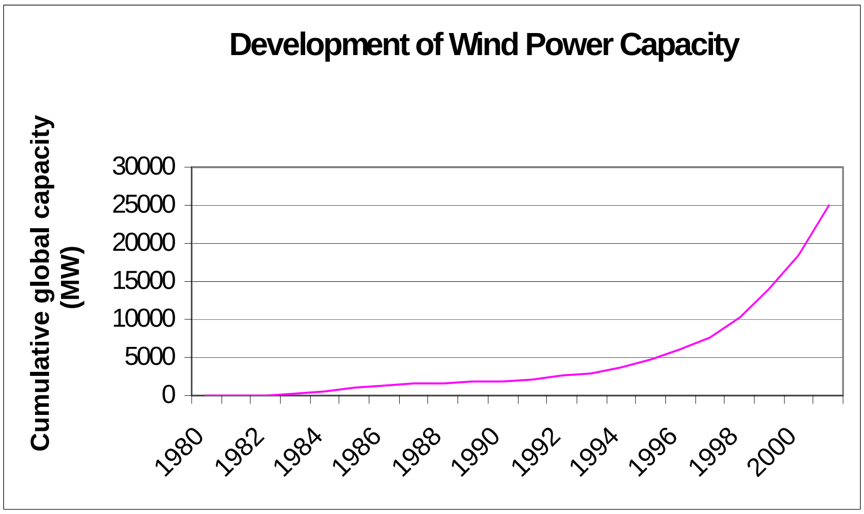

Figure 1. The growth of cumulative capacity of wind power in the world. (Source: years 1980-1995 [5], years 1996-2001 [1].)

Wind power is renewable, practically emission-free, and at the same time very modern, using highly sophisticated technology. It stands for both a reduction of emissions from the energy sector and a development of a new branch of industry (turbine manufacture). Therefore it may be seen as an example of ecological modernisation, which has been defined as social development in which the interests of environment and economy are compatible [6, 7].

This paper is a part of a project in which wind power policy and its role in the development of the wind power sector in Finland are studied. In this article different scenarios of the development of wind power in Finland up to the year 2025 are presented. These scenarios were created by 14 experts and they describe both probable and preferable images of the future.

A number of typologies of different ways to make scenarios have been presented [8, 9, 10, 11, 12]. To frame the approach of the study, three basic methodologies of making scenarios can be discerned: 1) Business-as-usual modelling, 2) what-if modelling and 3) heuristic images of the future [12]. Deterministic business-as-usual modelling has long been a standard in technical and economic forecasting, but what-if modelling was increasingly used in the 1990's (e.g. Nakicenovic *et al.*, [13]). The 'softer' use of participants' future images is performed in this study. It is usually considered relevant in the analysis of novel phenomena with potentially growing importance, that is *weak signals*. Although the growth of wind power is a rather strong signal in international energy discussion, in Finland it is still weak (see above).

The scenarios presented here are not to be understood as predictions about the future, despite of the expertise of the people who designed them. Instead, they are used more as presumptive [14] or conjectural [8] beliefs of the future of wind power. It is important to study such beliefs because images about future, about what is possible and preferable, have an influence on targets set for policy. The targets, in turn, are important, because the global wind power capacity has grown largely as a result of determined wind power policies of different countries [15]. The images of preferred and probable future, such as presented in this study, enable the setting of political goals, the search of means, as well as the systematic comparison of different actors' objectives, arguments, and values.

2 Material and methods

The empirical material for the study was collected with a questionnaire and interviews in the spring and summer of 2002. The questionnaire was sent to 22 wind power experts of which 18 returned it. Four participants filled the questionnaire incompletely, and their views are not used in this article. Thus the material consists of 28 cases, of which 14 responses of the probable future and 14 responses of the preferable future. The quantitative responses were grouped by cluster analysis as 28 scenarios are too many to be illustrative. The emerging clusters were complemented by qualitative analysis of the interviews. A somewhat similar approach has been used by one of the authors previously in analysing the future prospects of transport [12,16].

2.1 Experts

The interviewees were chosen through co-nomination, where the first interviewees suggest further experts to be included in the study. This method has been criticised, because if the original group of interviewees is biased in some way, the final list of participants is likely to be skewed in a similar way. Therefore the original group was chosen carefully to cover the wind power sector in Finland, so that all relevant fields (research, policy making and implementation, business community, and lobbying groups) were represented[2].

Some of the chosen experts are part of the wind sector itself, others have wind power as only one of their professional concerns. For example, representatives of the Parliament, ministries and different lobbying groups each have a role in the designing of wind power policy, which in turn affects the development of the sector. Their expertise ranges from the production of wind turbine components to the understanding of wind power policy and the political processes of designing it. Full list of interviewees is included as Appendix 1.

Only two of the interviewees were female, and most (12 of 14) had a degree in technological or natural scientific fields. In fact, only one had not graduated from a university. While it is clear that this group of experts does not mirror Finns in general, it is thought to be representative of the wind power sector and of the sectors influencing wind power. The Finnish wind power sector, consisting largely of companies producing turbines, their components and materials, as well as of the research sector, is dominated by technological and natural scientific expertise. The same applies to a large part of the lobbying groups representing industries and the energy sector, and even to the Ministry for Trade and Industry. The gender bias seems to reflect the reality of wind power sector in Finland.

[2] The consumers of wind electricity were excluded from the study, as the emphasis was on wind energy policy, which the consumers influence only indirectly.

The experts were chosen from different organisations, but in this study they only represented themselves, as individuals, and were promised anonymity in respect to individual statements. This strategy allowed the interviewees to give their honest opinions instead of political statements of their organisations. In addition, it was possible to discuss their values and other personal issues, which had an impact on the ”preferable” futures. A downside of anonymity is, that the analysis is less transparent but in this study it does not matter who holds which views, only the views themselves are discussed (see e.g. Kuusi [17]).

2.2 Variables

The 28 cases or future images presented in this text were sampled from the numerical answers in the questionnaire. Even though the original questionnaire contained several issues, only three key variables were chosen for the scenarios, namely the installed capacity of wind power in Finland, the electricity produced with the said capacity, and the consumption of electricity in Finland. All three figures were collected for the years 2010 and 2025, for both probable and preferable futures.

The installed capacity of wind power is often used as the yardstick with which to measure the development of wind power sector in Finland. Capacity does not depend on site-specific conditions, and official targets are also most easily expressed as the installed capacity. However, the electricity produced with the said capacity is more important, as it is the electricity which is in demand in the society, not power plants themselves. The combination of the two, electricity produced by certain capacity, can also be used to indicate how wind power technology develops over time.

We wished to set wind power in a context, so we also asked about the overall electricity consumption in Finland. This indicates not only how important wind power becomes in the energy sector, but also how the electricity market itself is changing.

We also asked how the gross domestic product (GDP) would change in Finland. It was meant to be used in combination with the total consumption of electricity, to see whether there would be changes in the electricity intensity of the economy. However, the question was excluded from the scenarios as there was not a sufficient number of quantitative answers to it.

2.3 Time scale

Years 2010 and 2025 were chosen because they are the years used in the Finnish “Action Plan for Renewable Energy Sources” [18], the most important political plan for the Finnish wind power policy. It is the result of a committee set by Ministry for Trade and Industry (responsible for energy policy in Finland). The committee had members from e.g. different ministries, non-governmental organisations and other lobbying groups, as well as the research sector. In fact, it was mainly from the organisations which participated in the committee drafting the Action Plan that the respondents for this study were chosen. The Action Plan was endorsed by the Parliament. A proposal for an update of the Action Plan was produced recently [19].

It would have been analytically more clear to use evenly spaced years 2010 and 2020, and possibly 2030 as reference points in the scenarios. However, it was felt to be most informative to use the same years as those given in the Action Plan, as this made comparisons to official documents possible. In the questionnaire, background figures were given for years 1980, 1990 and 2000. As for wind power capacity they were 0, 0.3 and 40 MW, respectively [20]; for wind power production 0, 0.5 and 77 gigawatthours (GWh), respectively [20]; and for total electricity consumption 40, 60 and 80 TWh, respectively [21].

Many experts complained about the long time scale, stating that it was impossible to speculate about events that far away in time. However, a shorter time scale would not have revealed changes that take longer to emerge. In that respect, an even longer time scale would have been preferable.

2.4 Probable and preferable futures

Each expert who participated in the study was asked to express his/her probable and preferable image of the future in the questionnaire. Probable future was defined simply as the future the expert considered most probable, whereas preferable future was defined as the possible future the interviewee would like to see take place (see Amara [10]). It is important to note that the response of the preferable future was supposed to be possible in technical, economic and social terms, according to the respondent. While the preferable future of one expert is not necessarily possible in the opinion of another, perceived possibility was used in the definition. Probable and preferable futures were examined separately, so that each person produced two cases. These have been marked as ”pro” and ”pre” in the following tables and figures.

2.5 Cluster analysis

The cases were grouped by hierarchical cluster analysis found in the SPSS 11.1 software, using the furthest neighbour clustering algorithm. As the three key variables were on different numerical scales, they were standardised to the scale 0…1, that is the highest value got the numerical value of 1.00 and the rest were given values linearly downwards. The normal Euclidean dissimilarity measure was used as all the variables were on relative scale.

All three variables were given equal weight in the clustering. The first two (capacity and electricity produced with the said capacity) are obviously not independent. As the main interest here was in the future of wind power, and the electricity production so heavily depends on the available capacity in reality as well as in these cases, it was deemed acceptable to use no weighting. The changes in electricity consumption are of secondary importance here, though by no means irrelevant.

Hierarchical cluster analysis cannot ultimately make the choice of the number of clusters. How does a researcher know whether the number of clusters reveals the grouping present in the data? There seems to be no consensus on the matter in the literature of classification. Five strategies might be useful: 1) statistical stopping rules; 2) external material; 3) theoretical categorisation; 4) applicability to decision-making; 5) heuristic sense-making [22, 23, 16]. We used strategies 2, 4 and 5.

The problem of the statistical stopping rules is that the rules are made and tested by using artificial data in which clusters do exist. The artificial composition of the data might have a serious bias when applied to real data in which, by definition, the grouping cannot be known beforehand. External material might be useful but when tested quantitatively, it would mean that some of the key variables should be left aside from clustering. Hence, we used the qualitative material from the interviews as a test for the sensibility, although we did not use it in the grouping. Theoretical categorisation might also be used but we were not aware of an applicable theoretical typology of different views of the future of wind power. The criteria of applicability to decision-making and heuristic sense-making were thus used. The first supposes a default number between 4 and 7 [24, 16]. The final choice was made by studying clustering dendrograms and the differences between the clusters. The quantitative clusters were constructed to scenarios using the qualitative material from the interviews.

2.6 Interviews

The interviews lasted 1-2 hours each and covered a number of topics, such as costs and benefits associated with wind power, availability of knowledge on wind power, different actors' influence on the growth of the sector in Finland, the likely development and desirability of policy instruments, and the development of wind power technology and costs. The questions were not identical in the interviews, though the themes remained the same. Interviews were taped and transcribed before analysis.

After the cases had been grouped into clusters, explanations for the differences between clusters were searched for from the arguments given in the questionnaires and interviews.

The clusters are presented below in figures and numbers. Section 4 contains the arguments behind the numerical values.

3 Clusters in numbers

The most illustrative output form of the hierarchical cluster analysis is the dendrogram (Fig. 2), as it shows clearly which cases are grouped together at each phase. Drawing vertical lines helps in determining the choice of an appropriate number of clusters. Considering this data it seems that possible numbers would be 3, 4, 5, 6 or 9. Choosing three or fewer would result in clusters of very different size. Nine clusters would not be very illustrative. Choosing six clusters seems to only produce another outlier as compared to choosing five. Shifting from four to five breaks a bigger cluster in two, and as the number 5 falls into the range of 4-7 it might be useful for decision-making. However, we invite the reader to ponder whether clusters 2 and 3 are so close to each other that they should be further combined. Or, should cluster 3 be divided in two, resulting in six clusters?

The five clusters are presented in Table 1 in detail.

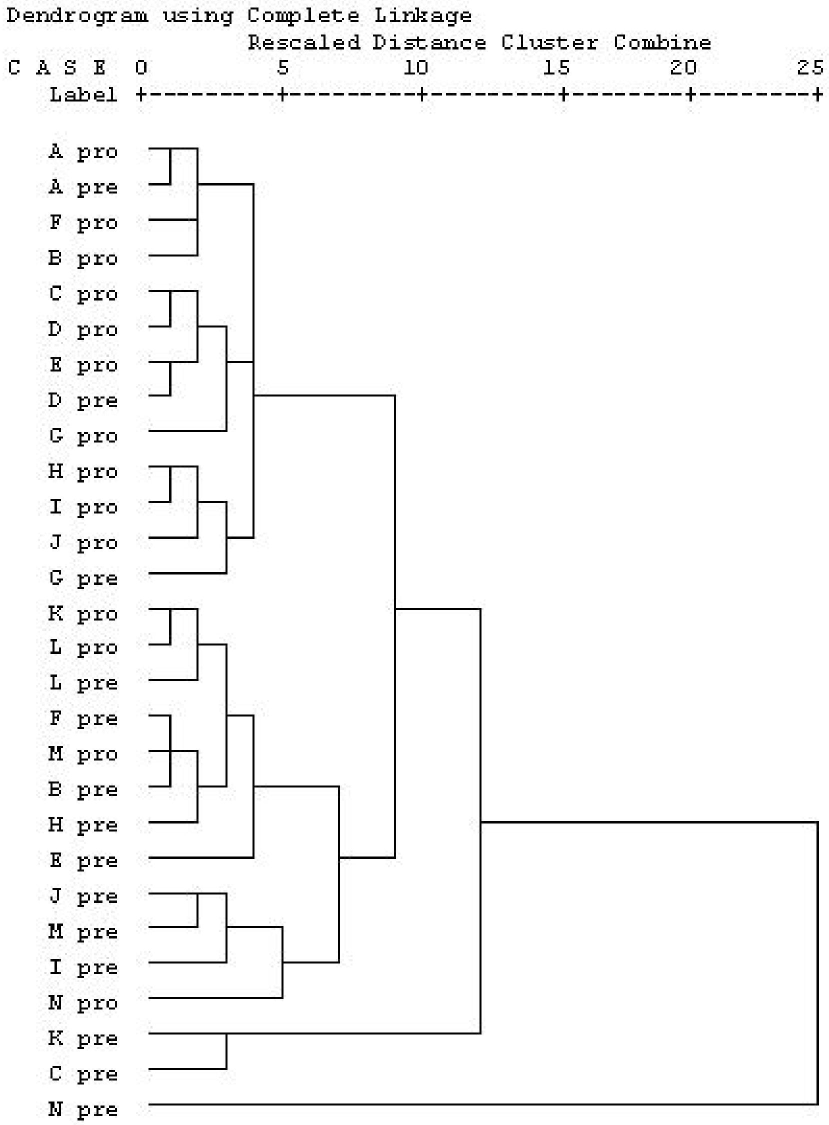

Figure 2. Clustering dendrogram using the furthest neighbour method. The block letters stand for the respondents, the abbreviation “pro” means probable future and “pre” means preferred future.

Table 1. Details of the cases grouped into five clusters.

	Case	Wind capacity 2010 MW	Wind capacity 2025 MW	Wind electricity 2010 GWh	Wind electricity 2025 GWh	Electricity consumption 2010 TWh	Electricity consumption 2025 TWh	[a]Share of wind in el. cons. 2010 %	[a]Share of wind in el. cons. 2025 %
Cluster 1									
	[b]A-pro	500	1250	1000	3000	93	100	1,08	3,00
	[b]A-pre	500	1250	1000	3000	93	100	1,08	3,00
	F-pro	300	2000	700	4800	90	110	0,78	4,36
	B-pro	300	2500	740	6200	95	100	0,78	6,20
	C-pro	200	700	447	1564	92	107	0,49	1,46
	D-pro	300	700	600	2000	90	105	0,67	1,90
	E-pro	200	1300	400	3000	90	100	0,44	3,00
	D-pre	300	1000	600	3000	90	100	0,67	3,00
	G-pro	200	500	400	1000	95	120	0,42	0,83
	H-pro	300	2000	650	4500	100	120	0,65	3,75
	I-pro	300	2000	720	5200	104	120	0,69	4,33
	J-pro	250	1500	500	4000	100	110	0,50	3,64
	G-pre	500	1500	1000	3000	100	130	1,00	2,31
Mean		**319**	**1400**	**674**	**3405**	**95**	**109**	**0.71**	**3.11**
Cluster 2									
	K-pro	500	2000	1200	6000	90	95	1,33	6,32
	[c]L-pro	450	2000	1200	6000	90	100	1,33	6,00
	[c]L-pre	550	2200	1320	7200	85,5	95	1,54	7,58
	F-pre	500	3600	1200	8600	90	100	1,33	8,60
	M-pro	500	3000	1100	8000	90	95	1,22	8,42
	B-pre	500	3000	1200	7500	95	100	1,26	7,50
	H-pre	500	4000	1100	10000	90	90	1,22	11,11
	E-pre	500	2500	1000	6000	80	70	1,25	8,57
Mean		**500**	**2778**	**1165**	**7413**	**89**	**93**	**1.31**	**7.96**
Cluster 3									
	J-pre	750	3000	2000	8000	90	100	2,22	8,00
	M-pre	1000	3000	2000	8000	90	100	2,22	8,00
	I-pre	1000	4500	2700	12000	95	100	2,84	12,00
	N-pro	500	5000	1000	12000	95	120	1,05	10,00
Mean		**813**	**3875**	**1925**	**10000**	**93**	**105**	**2.08**	**9.52**
Cluster 4									
	K-pre	1500	4000	4000	12000	85	80	4,71	15,00
	C-pre	1500	4000	3352	8940	92	92	3,64	9,72
Mean		**1500**	**4000**	**3676**	**10470**	**89**	**86**	**4.15**	**12.17**
Cluster 5									
	N-pre	**3000**	**15000**	**6000**	**37000**	**88**	**100**	**6.82**	**37.00**

[a] Market shares were not specifically asked for. They were calculated from values in the previous four columns.
[b] Respondent A gave ranges. The arithmetic means of the given ranges were used.
[c] Respondent L gave numbers including symbols <, > and >>. These were interpreted as ± 10 % (<, >) and + 20 % (>>).

The following three figures (3-5) display the arithmetic means of each variable in the clusters. For example, cluster 1 had 13 answers to “how much wind power capacity will there be in 2010”, and the mean 319 MW has been used in Figure 3. In addition to the five pillars signifying the five clusters, there is a pillar marked “WG”, which stands for the “target” (in case of 2010) and “vision” (in case of 2025) of the working group proposal for the update of the Action Plan [19]. Even though the proposal has not yet been adopted as state policy, it can be said to represent the newest (semi-)official view of the future of wind power in Finland.

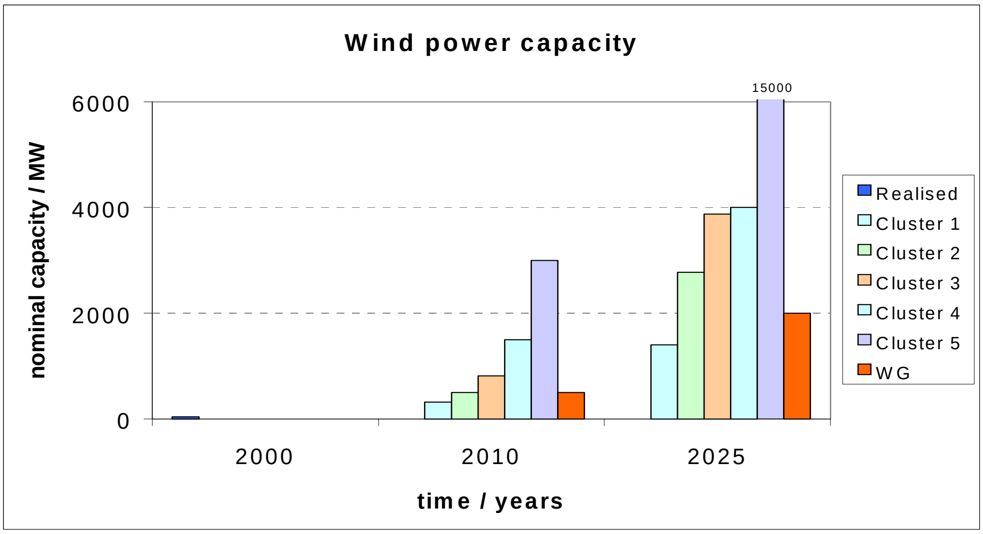

Figure 3. Wind power capacity in Finland in 2000 and six scenarios for the years 2010 and 2025. Note that x-axis (time) is not on scale.

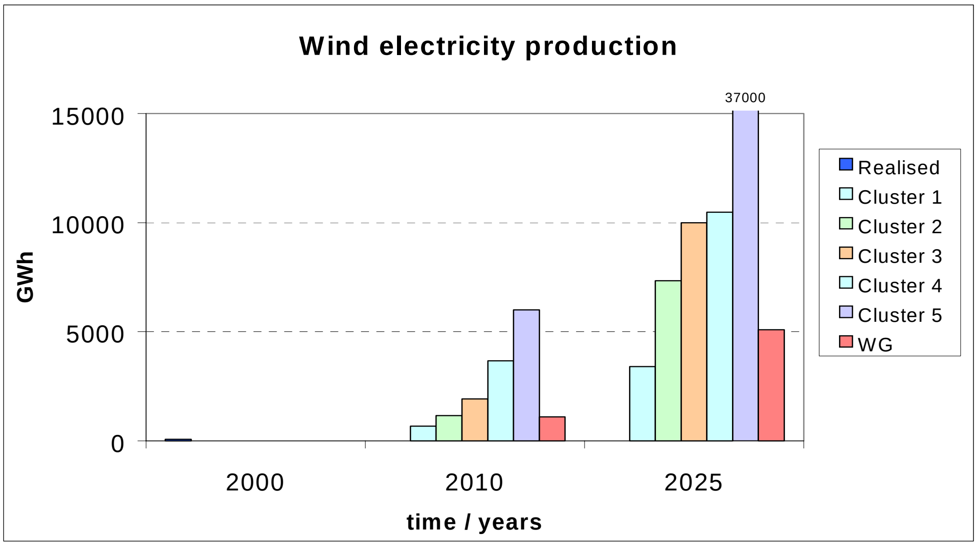

Figure 4. Production of wind electricity in Finland in 2000 and six scenarios for the years 2010 and 2025. Note that x-axis (time) is not on scale.

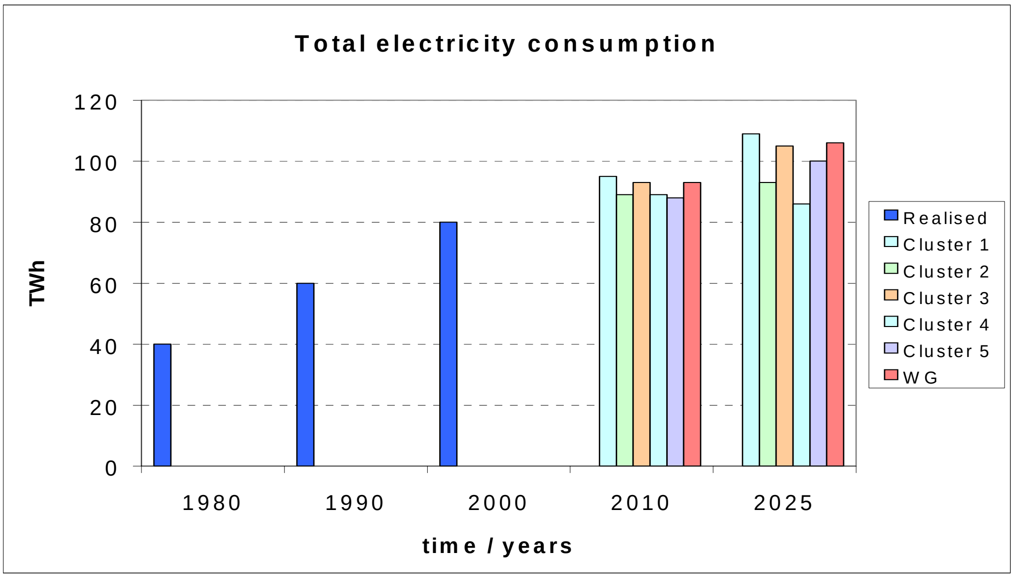

Figure 5. Consumption of electricity in Finland 1980 – 2000 and six scenarios for the years 2010 and 2025. Note that x-axis (time) is not on scale. Value for consumption was not given in the WG, but is calculated from the values for electricity production from renewable sources, and the share of such electricity in total consumption.

Table 2 presents the share of wind electricity of the total electricity consumption in Finland. The share grows from cluster 1 to 5, and also grows over time, from 2010 to 2025 in each cluster.

Table 3 contains a factor that tells how much electricity is produced with the installed capacity (=production factor). This factor has been rather small in Finland, at least partly as a result of relatively slow wind speeds. Growing factors in the scenarios were usually attributed to the improving technology and to offshore installations (the wind speeds are higher at sea, giving better yields). In this paper the production factor is calculated as gigawatt-hours per megawatts, resulting in figures between 2 and 3.

There was an improvement in all clusters in respect to this factor, but the change was more marked in some clusters. However, as there was significant variation within clusters, and moreover as the differences are minor, no special emphasis should be given to such differences. Of more importance is the fact that all clusters include some improvement, and that while the improvements are significant, the numbers are not very high even in 2025.

Table 2. Share of wind electricity in the electricity consumption in Finland (percent).

	2000	2010	2025
Realised	0.1		
Cluster 1		0.7	3.1
Cluster 2		1.3	8.0
Cluster 3		2.1	9.5
Cluster 4		4.2	12.2
Cluster 5		6.8	37.0
WG		1.2	4.8

Table 3. Factor of yearly produced electricity by installed capacity (gigawatthours per megawatts).

	2000	2010	2025
Realised	2.02		
Cluster 1		2.11	2.43
Cluster 2		2.33	2.67
Cluster 3		2.37	2.58
Cluster 4		2.45	2.62
Cluster 5		2.00	2.47
WG		2.20	2.55

4 Scenarios: going behind the numbers

In this section the quantitative clusters are complemented to scenarios with the qualitative material from the interviews. In order to protect the anonymity of the respondents we refer to all respondents with the pronoun “he”.

4.1 Working group proposal

The values for wind power in the working group proposal are based mainly on the original Action Plan for Renewable Energy Sources [18] and in the Background Report for the Plan [25]. The values given for the year 2025 are not considered a target but rather an estimate about development possibilities. It is acknowledged that in the long run wind power has potential for much greater use than 2000 MW in Finland, but the working group considered reaching this capacity by 2025 very challenging in regard to the present level.

The values for installed capacity in 2010 were based on data about the wind conditions in different parts of the country as well as information about the grids and existing land-use plans. However, the estimates were slightly higher than what the existing information allows for. For example, there is no reliable data on inland wind conditions, but in the Background Report 50 MW were estimated to be built inland by the year 2015. Estimates for technical potential for wind power in Finland have become higher since the Background Report [26], but there were no references to this in the working group proposal.

In the Background Report there are references to the lowering of the wind power costs as a result of learning, but there are no estimates as to how fast the further development would be, nor what the costs would be in any given year. There were no estimates about the increasing competitiveness of wind power in the working group proposal, even though competitiveness was named as the primary goal of renewable energy policy. This issue was not mentioned when discussing the future need for subsidies, either.

There were many policy suggestions for supporting specifically wind power in the working group proposal, but they were mostly only recommendations to further study and develop the policies. The main emphasis in all plans to increase the share of renewables in the Finnish energy supply is on biomass, in fact bioenergy is expected to fulfil 90 % of the total increase in renewable energy production.

Estimates about the electricity consumption were based on the business-as-usual scenario presented in the National Climate Strategy [27]. It was estimated that the production of energy intensive industries would grow slower than the production on average. Population growth would be slow and stop around the year 2015. Energy taxes were expected to be raised in 2003. All these factors would reduce the rate of growth of electricity consumption. The working group proposal does not, however, discuss electricity consumption in detail but concentrates on the support of renewables.

4.2 Scenario 1: Calm

This scenario is based on the 13 responses in cluster 1. The first cluster differed less from the continuation of current trends than any of the other clusters, hence the name “calm” for the scenario. The wind power capacity grows least in this scenario, whereas the electricity consumption grows fastest. The factor of produced electricity to wind power capacity is low. The scenario of the working group is closest to this one, even though it is also close to scenario 2.

As this scenario consists of 13 responses, representing almost half of the cases, it is not surprising that there was a lot of variation in the arguments behind the numbers. It is possible to arrive at similar numbers from very different perspectives.

There are ten responses of the probable future in this cluster, and three preferable ones. The preferable futures of A, D, and G are not very different from their probable ones, in the case of respondent A the two are in fact identical. These three experts show a certain pessimism, as they did not expect wind power to be financially competitive without state support by 2025. People who only had their case of probable future in this cluster were much more optimistic about the competitiveness, but even though they expected wind power’s production costs to diminish, their main argument was that the price of electricity would rise. This would result from internalising the external costs of other, more polluting energy sources through environmental taxes, for example.

Many of those who had pessimistic probable futures in this cluster and more optimistic preferable futures in other clusters explained that they did not expect Finnish energy policy to support wind power as much as they hoped. In some cases the criticism was directed towards the quantity of support, but many also considered the existing instruments, mainly investment subsidy, to be unsuitable for large-scale development. Unless new policy instruments were taken to use, wind power would develop slowly in Finland.

Building wind power offshore has not started in Finland yet. The rate of building was considered rather slow in this scenario. Respondent G did not believe in large-scale building even in the long run, as he expected there to be both environmental and economic constraints. Most respondents, however, believe that offshore parks will meet with less public resistance, but building will be restrained by higher costs. With better wind conditions and fewer siting problems it was expected that the majority of Finnish capacity would be found offshore by 2025. By 2010 there would, however, be only one or two pilot parks, in which it would be tested how well the turbines and foundations can withstand the pressure of ice, for example.

Respondent J believed that Finnish companies would hesitate to commit to notable offshore investments, but that after 2010 also foreign companies would find the shallow waters of the Finnish coast.

Electricity consumption was expected to grow at least until 2025, though most believed that the rate of growth would be slower than in the past decades. In the case of G-pre the rate would stay at the level of approximately 20 TWh/decade. It would be preferable not only because electricity is an important factor of production, but also because electricity was expected to replace other sources of energy, especially in traffic. This would lower the emissions from total energy consumption. Most respondents, however, were unhappy about the continuous growth of consumption.

The respondents doubted that Finns would begin buying wind electricity voluntarily in a large scale. It was felt that there is a significant difference between Finns and people in e.g. other Nordic countries in the willingness to buy environmentally better but more expensive products.

There were two views among the respondents about the importance of the ”green” electricity market. Some argued that without the demand there would not be supply either, and that the state should not interfere with the market. Others called for the state to take the responsibility for the change. They felt the responsibility for the ”greening” of the electricity market should not be left to individual consumers. Respondent D was the only one to express doubts about whether wind electricity is, in fact, environmentally very beneficial.

4.3 Scenario 2: Breeze

There were eight cases in cluster 2, three probable ones and five preferable ones. The cluster was more optimistic in terms of wind power growth than cluster 1, but more pessimistic than the other three.

In this scenario the growth of wind power capacity is seen to be constrained by environmental and economic factors. It is difficult to find more suitable sites. The respondents believed that especially in the short run (up to 2010) there will be bureaucratic constraints. Land-use planning practices have not yet been developed to take wind power sufficiently into consideration in Finland. Offshore development is not believed to proceed rapidly before 2010.

Several respondents argued that the current Finnish wind power policy is not very effective, or pro-active enough. Some respondents did, however, find the investment subsidy to be a rather practical tool. For example, respondent L points out that with this instrument it is possible to direct more support to certain energy forms. In contrast, if wind power had to compete against other renewables on equal terms, it would probably lose. He points out that electricity produced from biomass is currently cheaper than wind electricity.

Estimates about the technological development are rather optimistic in this scenario, perhaps reflecting the fact that there are so many cases of preferable future. It was also pointed out that current turbine size in Finland is small, but is expected to grow significantly, improving the cost-effectiveness.

After 2010 wind power will gradually become competitive without financial support mechanisms in this scenario. The price of other electricity forms, especially fossil fuels, was believed to rise as a result of internalising the external costs. Respondent B, for example, expected “green” electricity to become rather redundant by 2025, as all electricity production would be less polluting than nowadays.

Electricity consumption grows also in the cases of this scenario, but respondents expected a saturation point to be reached. This would result largely from efforts in energy conservation, taking place both in industry and households. Also “natural” factors like the ageing of population would contribute.

4.4 Scenario 3: Brisk wind

Cluster three had four cases, three of which were of preferable future. This scenario is characterised by relatively high growth of both wind power and electricity consumption. The share of wind power in electricity consumption is almost 10 percent by 2025, which represents a great change from the current situation of 0.1 percent.

As electricity consumption also grows significantly, and presumably the economy with it (alas, it was impossible to use GDP in the scenarios), this scenario seems to represent ecological modernisation. Reduced environmental impact coexists with economic growth.

All four respondents seemed to agree that the main impediment which prevents the preferable future from being probable is Finnish energy policy. First of all, they did not consider the current policy to be consistent enough. It was also argued that the main instrument, investment subsidy, is ineffective at least in its current form, where subsidies are directed to pilot and demonstration projects. In addition to measures that support wind power directly, the respondents called for stricter taxes or other environmentally motivated instruments, which would raise the price of more polluting energy sources.

According to respondents J, M, and I such policy measures could result in the preferable development seen here. In the theory of ecological modernisation it has also been expected that increased policy measures would be needed [7]. In this respect, as well, the scenario is in keeping with the theory. The importance of the public sector was evident also in the way it was urged to show good example by buying “green” electricity.

However, N considered the wind power capacity of this case almost a minimum level, saying that ”the share of at least some 10 % seems to be inevitable”. His preferable future case included much higher values. It was this case (N-pro) which would have formed a cluster of its own, if we had chosen six clusters instead of five. In the light of the arguments presented above, it seems that it could have been a reasonable choice.

The criticism against Finnish policy makers was a unifying factor, however. For example, N criticised the Finnish policy makers for almost wilful blindness to learn from the experiences of other countries, from the reports of international organisations, etc. Especially from respondent M there were also complaints against environmental officials for paying too much attention to issues of secondary environmental importance (such as noise and impact on landscape).

Respondents I and J expected significant improvement in the production factor to take place already between the years 2000 and 2010 (increase from 2.02 to 2.66). One of the causes of this increase in productivity are offshore plants, of which there are much more by 2010 in these preferable futures than in the probable ones. On the other hand, M and N did not foresee a notable change in productivity before the period 2010 - 2025.

In all the cases electricity consumption was going to increase. One of the factors contributing to that, according to respondents J and N, was the recent decision to build a fifth nuclear reactor to Finland, which they believed would give the energy intensive industry a boost. Respondent I had similar thoughts, but in his preferable future case the new nuclear power plant would not be built after all. Respondent M did not believe that wind power would suffer from nuclear power, as he argued that the motive to build each is different (nuclear power provides a steady supply for industrial needs whereas wind power is useful for environmental reasons). Interestingly, M had a slightly higher value for electricity consumption in this preferable future case than in the probable one. This development would be preferable especially for wind energy because it would mean higher demand.

All respondents were rather relieved, however, that the long nuclear debate was finally over. They stated that as the environmentalists had often brought up wind power as an alternative for nuclear power, and the powerful pro-nuclear faction had responded by downplaying wind power's potential, the altercation had rendered any normal work practically impossible.

4.5 Scenario 4: Storm

Cluster 4 was the first cluster that had only cases of preferable futures, and only two of those. This scenario is characterised by high growth in wind power but slow growth and later even a small decrease in the consumption of electricity. This seems to indicate ecological structural change, i.e. "delinking economic growth from the consumption of ecologically significant resources, like energy and materials" [28].

The respondents argued that it would be possible to stop the growth of electricity consumption with more efficient use of energy. This growth in efficiency would require political measures, which would raise the price of electricity. Too low prices are likely to increase the use of electricity, for example in space heating.

Especially respondent K emphasised the importance of knowledge and technology in economy. As long as the price of electricity remains at a low level, there is an incentive to invest in energy-intensive industry, which he did not consider optimal for the development of the country, the environment, or the economy in the long run.

In K's opinion the current energy discourse pays too much attention to the price of electricity. He argued that in the free electricity market only price matters, and factors like new technology or environmental issues do not give a significant edge in the competition. Therefore what is needed for a more sustainable future is political will, demonstrated as both declarations and policy instruments, through which environmental issues would be made to matter.

Neither C nor K had a very high opinion about the environmental consciousness of Finns. They did not believe that consumers would start buying “green” electricity, but they both believed that wind power would benefit significantly from a market mechanism that would differentiate between different sources of energy. Therefore in this scenario wind electricity would be sold mainly as “green” electricity, but this would be the result of officially set quotas. Wind power would be competitive without financial support mechanisms sometime after the year 2010, certainly well before the year 2025, but it would continue to be sold as “green” electricity.

The competitiveness is reflected also in the high production factor for 2010. In their scenario, C and K referred to such technological advances as growing turbine size, and starting the production at lower wind speeds. Also the economics of scale achieved with larger projects would lower costs.

Even though the importance of political measures was emphasised, both respondents criticised the use of investment subsidy, considering it a very inefficient tool for creating a viable market for wind power.

In fact, suitability and effectiveness of policy instruments were argued rather heatedly in all interviews. Some considered the existing policies to be almost a hindrance to wind power development in Finland. There was not a single policy instrument suggested that would have won the approbation of all interviewees, though R&D funding and information guidance were rather popular. The deepest gap was between those advocating instruments that would lower the costs of wind power technology (such as the investment subsidy) and those arguing for instruments that create market pull (such as feed-in tariffs or mandatory quotas for green electricity). It can be argued that the first type of policy measures are likely to benefit the Finnish wind power industry most, but they were also considered by some to be the most appropriate for liberalised electricity market. On motives for wind power policy in Finland, see Varho [29].

4.6 Scenario 5: Hurricane

Cluster 5 had only one case (N-pre). It is in a league completely of its own, with its 37-percent-share of wind electricity in consumption. Here the capacity in 2025 is extremely high, in fact it is three times as much as the second highest value given in all the other cases. Consequently the wind electricity production is also high, though the production factor is low, only 2 in 2010 and 2.47 in 2025.

Not surprisingly, N attaches very positive values to wind power, emphasising the environmental benefits. He argued that even compared to the other renewable energy sources, not to mention fossil fuels, the ecological impact of wind power is quite low. N also emphasised the huge resource of wind energy, saying that even in Finland only a small fraction of this resource would have to be utilised in order to provide a significant share of electricity (e.g. 20 percent).

In this scenario the very large capacity in 2025 (15 000 MW) would be achieved through offshore parks (12 000 MW) and also the use of inland resources as well as small-scale applications. For example, structures from lampposts to radio link towers and roofs of supermarkets could be utilised for small turbines, often using vertical axis solutions. The efficiency of such turbines, as well as large turbines in inland locations, would be lower than that of large turbines in better locations. This would lower the productivity of the installed capacity, but allow for much more installations, which in turn would allow economics of scale to reduce the costs of wind power.

Political will is a key to this scenario, as it was to scenario Storm. N proposed certain policy measures, which he argued would not cause undue financial strain to any actors. Unlike most other experts, N did not give technological research of wind power a high priority. He argued that what matters most is taking the existing technology to large-scale use, instead of waiting for further technical development. N also referred to learning rates, and estimated that the costs of onshore wind power would be reduced by 20-40 % within the decade, as a result of capacity being built to the European Union. For offshore the cost reduction would be even more remarkable, as its development is in an early phase.

One of the main measures that would improve the competitiveness of wind power would be the introduction of higher taxes for more polluting forms of energy. N believed that if all the costs were truly internalised, this alone would allow wind power to compete successfully. In the beginning (2010) wind power would be sold as “green” electricity, but by 2025 it could compete on its price alone.

Problems in siting N expected to be less severe than some other interviewees envisioned, as people would grow accustomed to the turbines and learn to consider them normal and even beautiful additions to the landscape. This, according to him, has been the case in countries where there is a lot of wind power.

Consumption of electricity would increase from the current level, but more slowly than during the last decades. It would even be possible to stop the consumption at the level of 100 TWh yearly, but this would require much more attention to energy saving than is the case today. Low price of electricity was considered also in our last scenario to be a deterrent for the efficient use of energy.

5 Discussion

In this study Finnish experts presented their images of the probable and preferable futures for wind power. It was noticeable that there was less variation in the probable futures than in the preferable ones. Does this mean that they are really more probable, more likely to take place in reality?

Not necessarily. First of all, for some it was preferable to have as much wind power as possible, for others the maximum scenario might have been different from the preferable one they presented. Therefore those who advocate wind power would have higher values in their preferable future images than those who oppose it, causing naturally more variation among the images of preferable future.

More importantly, however, these scenarios should not be considered in the light of probabilities. Instead, we should consider what causes the differences between them. For example, the respondents attitude towards wind power is important, as demonstrated in the previous paragraph. Certainly the attitude could be observed to be quite different between those who believed that wind power would remain marginal in the electricity sector in Finland, in the shadow of biomass, and those who believe that wind power could supply ten percent or even a third of Finnish electricity.

Secondly, some thought that even though increasing the share of wind power is desirable, since everything that can be done for wind also will be done, there is no difference between probable and preferable futures. Others believed that effective policy instruments could be taken to use if there was sufficient political will, but as it is lacking, the full potential of wind power will remain unrealised. This shows how the difference may not lie in the attitude towards wind power, but in the belief of what is socially and politically possible.

The scenarios created in this study were found not to be entirely consistent, as the arguments varied between the different cases in some clusters. This obviously resulted from the way they were crafted from numerical data before the analysis of arguments.

This was particularly noticeable among the images of probable future. Even though the numerical responses were relatively similar, the reasons leading to such development varied. The relatively slow growth of wind power capacity (compared to e.g. Germany and Spain [1]) envisioned in these cases was blamed in some cases on the lack of market for wind electricity and the high costs of the technology, in other cases on the lack of political will to create such a market which would lead to lower costs. Therefore, even if it would be possible to consider some value for the “material” issues (such as wind power capacity) here probable, it would tell us little about the societal and technical development in this sector.

When it comes to the total consumption of electricity, both the numbers and arguments were much closer to each other in the different scenarios. Still, there were significant differences. The experts mainly believed that the growth of consumption would slow down but nevertheless continue, or at best stabilise after 2010. There were only two responses (both preferable) where the consumption was less in 2025 than in 2010.

The growth of electricity consumption was mainly seen as a negative development[3], but a few interviewees considered electricity in a more positive light as a factor of production, and also as a means to reduce the emissions from the energy sector in general.

The reduction in the growth rate was expected to result from both “natural” factors, such as the ageing of the population, and from “political” factors such as the rise of electricity prices as a result of environmental taxes and energy conservation policies. A change of focus in the national economy to less energy intensive fields, where knowledge and expertise are most important, was considered to be partly natural process, partly a result of technology and education policies.

[3] The same conclusion can be made considering road traffic volume in a study on the future of Finnish transport [12].

Even though there were not sufficiently many numerical answers about the growth of GDP to include it in the scenarios, some estimates about the electricity intensity of the Finnish economy were made. In all but two responses it was expected that the electricity intensity of the economy would decrease in the future, even though it has grown over the past decades. In the remaining two responses the intensity stayed on the level of the year 2000. However, some interviewees who did not submit numerical estimates expressed their worry that the current energy policy that was seen to emphasise the importance of cheap electricity, could lead to increased investments into energy intensive industries.

These scenarios have allowed us to consider differences in attitudes and beliefs about factors affecting the development of wind power. Their main benefit, however, is in seeing how different targets there are for wind power, and how important the setting of a national target may be. Also, using the heuristic approach with qualitative interviews may provide energy modelling with new variables. For example, the role of policy making seems essential.

All interviewees were aware of the official target of 500 MW by 2010, in fact, many had been part of the working group that came up with this target. The official status of the target was considered quite important: several interviewees said that as the government had committed to this goal, it was going to find the means to reach it, as well. (It is notable that some were pleased with this, others considered it a less-than-rational approach.)

The importance of this target was also evident, when one respondent argued that he cannot create preferable and probable future images that are very different from one another, because he trusted in the values given by the experts for the Action Plan for Renewable Energy Sources and its Background Report. However, the person responsible for the wind power section of the Background Report also submitted two scenarios, and they were not identical. The reliance on expertise can be excessive.

It is well-known that some predictions may be self-fulfilling [10]. Is it possible that this target of 500 MW in 2010 and "vision" of 2000 MW in 2025 will also prove to be so? Do they limit our view of what is possible in Finland? The development of the global wind power market was very rapid during the 1990s, and some countries built hundreds or thousands of megawatts of wind power in a year. Can we really make any kinds of estimates about the state of wind power in Finland in 2025?

The vision of 2000 MW by the year 2025 was created in 1999 and adopted for the new working group proposal, as well. The estimates according to the experts interviewed for this study varied from 500 MW to 5000 MW in probable cases, and 1000 MW to 15000 MW in preferable ones. All of these numbers were considered possible. (The highest value, 15000 MW would probably be considered quite impossible by some experts, but even if we excluded N's cases, the highest value would be 4500 MW, that is 2.25 times the vision of the working group.)

Are we constricted in our thinking by the official targets and visions, or are they in fact an inspiring goal, an almost unattainable level? There is no simple answer to this, but certainly the official targets seem rather conservative in relation to the scenarios put forward by the experts in this study. It seems that it is necessary to continue to look at other, more varied visions of what is possible and preferable, in order to build a sustainable wind power sector for Finland.

Acknowledgements

Financing for this study by the Academy of Finland is gratefully acknowledged, as are the valuable comments given at many stages of the process by professor Ilmo Massa.

Appendix 1:

Experts participating in the study ”Future of wind power in Finland”

Name	**Education**	**Organisation**
<u>Provided cases:</u>		
Esa Holttinen	M.Sc. (Tech.)	Electrowatt-Ekono (consultant)
Hannele Holttinen	M.Sc. (Tech.)	VTT, Technical Research Centre of Finland
Aarne Koutaniemi	M.Soc.Sc.	Lumituuli Ltd. (a small wind power producer)
Ari Lampinen	M.Sc. (Tech.)	University of Jyväskylä
Peter Lund	D.Sc. (Tech.)	Helsinki University of Technology
Folke Malmgren	M.Sc. (Tech.)	Vindkraftföreningen (Wind power association)
Bernt Nordman	undergrad., env. science	Natur och Miljö (a nature and environment association)
Jaakko Ojala	M.Sc. (Phys.)	Ministry of the Environment
Esa Peltola,	M.Sc. (Tech.)	VTT, Technical Research Centre of Finland
Jouni Punnonen	M.Sc. (Tech.)	TT, The Confederation of Finnish Industry and Employers
Bengt Tammelin	M.Sc. (Phys.)	Suomen tuulivoimayhdistys (Finnish Wind Power Association)
Martti Tiuri	D.Sc.(Tech.)	Member of Parliament, chairman of the committee for the future (2002)
Harry Viheriävaara	M.Sc. (Tech.)	Finergy, Finnish Energy Industries Federation
Sirkka Vilkamo	M.Sc. (Tech.)	Ministry for Trade and Industry
<u>Were interviewed but did not provide sufficient quantitative information for the scenarios:</u>		
Veli-Matti Jääskeläinen	M.Sc. (Tech.)	WinWinD (turbine manufacturer)
Jorma Keva	M.Soc.Sc.	Ministry of the Environment
Jerri Laine	Lic.Sc. (Tech)	TEKES, Technology Development Centre of Finland
Mauno Oksanen	M.Sc. (Tech.)	Vapo Oy Energia (medium-size producer of wind electricity)
Leo Parkkonen	LL.M.	Ministry of Treasury
Gustav Tallqvist	MD (pathology)	Oy Synoptia Ab (agent of BONUS Energy turbines in Finland)
Pentti Tiusanen	MD (surgeon)	Member of Parliament, chairman of the environment committee
Jyrki Virtanen	M.Sc. (Tech.)	Metso Drives Oy (producer of turbine components)
<u>Interviewed abroad:</u>		
Jochen Twele	D.Sc. (Tech.)	Bundesverband WindEnergie e.V. (German wind power association)

References

[1] BTM Consult AS. International Wind energy development -world market update 2001 & Forecast 2002 through 2006, 2002. (available at www.btm.dk)

[2] McGowan, J.G. and Connors, S.R.. Windpower: a turn of the century review. *Annual Review of Energy and the Environment*, 2000; 25:147-197.

[3] McDonald, A. and Schrattenholzer, L. Learning rates for energy technologies. *Energy Policy*, 2000; 129(4):255-261.

[4] Holttinen, H., Peltola, E. and Tuhkanen, S. Wind power in Finland - export prospects and emission reductions. In: Technology and climate change CLIMTECH 1999-2002, Final report. TEKES, National Technology Agency, Techonology Programme Report 14/2002. Helsinki, 2002.

[5] Brown, L.R., Renner, M., Halweil, B. (eds.). Vital Signs. Earthscan, London. 2000.

[6] Massa, I. Epävarman yhteiskunnan ympäristöpolitiikka. In: Massa, I. and Rahkonen, O. (eds.), Riskiyhteiskunnan talous. Suomen talouden ekologinen modernisaatio. Helsinki. 1995.

[7] Andersen, M.S. and Massa, I. Ecological modernization - origins, dilemmas and future directions. *Journal of Environmental Policy & Planning,* 2000; 2: 337-345.

[8] de Jouvenel, B. *The Art of Conjecture*, transl. by Lary, Nikita, Weidenfeld and Nicolson. London, 1967.

[9] Hirschhorn, L. Scenario Writing: A Developmental Approach. *Journal of the American Planning Association,* 1980; 46(2): 172-183.

[10] Amara, R. The Futures Field. Searching for Definitions and Boundaries. *The Futurist*, 1981; 15(1): 25-29.

[11] Nijkamp, P., Rienstra, S.A. and Vleugel, J.M.,: *Transportation Planning and the Future*. John Wiley & Sons, Chichester (UK), 1998.

[12] Tapio, P. Climate and traffic: Prospects for Finland. *Global Environmental Change,* 2002; 12(1): 53-68.

[13] Nakicenovic, N., Grübler, A. and McDonald, A., (eds.). *Global Energy Perspectives*, Cambridge University Press, Cambridge, UK, New York, NY, USA, 1998.

[14] Bell, W. *Foundations of Futures Studies: Human Science for a New Era. Volume 1: History, Purposes, and Knowledge*. Transaction Publishers, New Brunswick, 1997.

[15] Sawin, J.L. *The role of government in the development and diffusion of renewable energy technologies: wind power in the United States, California, Denmark, and Germany 1970-2000*. Doctorate dissertation, Fletcher school of law and diplomacy, USA. 2001.

[16] Tapio, P. Disaggregative policy Delphi. Using cluster analysis as a tool for systematic scenario formation. *Technological Forecasting and Social Change,* 2003; 70(1): 83-101.

[17] Kuusi, O. *Expertise in the Future Use of Generic Technologies: Epistemic and Methodological Considerations Concerning Delphi Studies*, Acta Universitatis Oeconomicae Helsingiensis A-159, Doctorate dissertation, Helsinki School of Economics and Business Administration, HeSE Print, 1999.

[18] *Uusiutuvien energialähteiden edistämisohjelma*. Kauppa ja teollisuusministeriön julkaisuja 4/1999. 33 pp. Helsinki: Edita, 1999. [Action plan for renewable energy sources. Ministry for Trade and Industry, Publications 4/1999. In Finnish, abstract in English].

[19] *Uusiutuvan energian edistämisohjelma 2003-2006, työryhmän ehdotus*. Kauppa ja teollisuusministeriön työryhmä- ja toimikuntaraportteja, 5/2003. Helsinki: Edita. [Action plan for renewable energy 2003-2006, A working group proposal. Ministry for Trade and Industry, Ad hoc committee reports 5/2003. In Finnish, abstract in English].

[20] Laakso, T. and Holttinen, H. Tuulivoiman tuotantotilasto. *Tuulensilmä* 3/2001; 12: 12-13.

[21] Kara, M., Mattila, L., Viinikainen, S., Wolff, J. and Lind, I. (eds.). Energia Suomessa. VTT Energia. Helsinki, 1999.

[22] Dubes, R. and Jain, A.K. Validity studies in clustering methodologies. *Pattern Recognition*, 1979; 11: 235-254.

[23] Milligan, G.W. Clustering validation: results and implications for applied analyses. In: Arabie, P., Huber, L.J. and De Soete, G. (eds.). Clustering and Classification, World Scientific Publ., River Edge, NJ, 1996.

[24] Robinson, J. Futures under glass: A recipe for people who hate to predict. *Futures,* 1990; 22(8): 820-842.

[25] *Uusiutuvien energialähteiden edistämisohjelman taustaraportti.* Kaupppa ja teollisuusministeriön julkaisuja 24/1999. 106 pp. Helsinki: Edita. [Background report for the action plan for renewable energy sources. Ministry for Trade and Industry, Studies and reports 24/1999. In Finnish, abstract in English].

[26] Kiviluoma, J., Lappalainen, I. and Mattila, V. *Tuulessa on voimaa*. Motiva Oy and OPET (Organisations for the Promotion of Energy Technologies) Finland. 2001. In Finnish.

[27] *Kansallinen ilmastostrategia. Valtioneuvoston selonteko eduskunnalle*. Kauppa- ja teollisuusministeriön julkaisuja 2/2001. Helsinki: Edita. [National climate strategy, Finland. Government report to Parliament. Available in English at: < http://www.ktm.fi/eng/3/3_6.htm> (May 26, 2003).]

[28] Simonis, U.E. *Industrial restructuring in industrial countries*. In: Ayres, R.U. and Simonis, U.E. (eds.). Industrial metabolism: Restructuring for sustainable development. United Nations University Press, Tokyo, 1994. p. 31-54.

[29] Varho, V. *Global benefits, local costs? - Motives for the Finnish wind power policy*. Paper presented at the 6th Nordic Conference on Environmental Social Sciences (NESS), June 12-14, 2003 in Turku, Finland.