Future Decentralised Energy Systems 2020

DECENT
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January 2002

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Introduction

In this paper the results from the future study on decentralised energy generation are presented.

It starts with some general remarks on how and when the survey was conducted, and who responded to the questionnaire.

The results from the survey firstly highlight the general framework topics important for the future decentralised energy generation. Secondly, the more technology statements are analysed, starting with the ranking of statements. The top ten topics, which are selected on the combined index of environmental impact and production cost impact, are presented and described. Furthermore, a short description is made regarding the remaining topics. For all topics as well as for single decentralised energy types, the time of occurrence and barriers/constraints for realising the statement are described. Finally, concluding comments from the respondents are summarised.

General remarks

The DECENT future study is basically designed as an adapted Delphi investigation. It is designed by an initial round of Decent expert discussion on central statements about the future development of decentralised energy generation. The second round consists of a larger anonymous survey among external experts about the future development of decentralised energy generation. The third round not included in this paper will be the internal Decent scenario building phase, which partwise will be performed in the Berlin workshop on 3rd/4th December 2001. The fourth round will concentrate on re-evaluating the scenarios. This will be conducted by a sub-set of seven external experts on decentralised energy generation.

The survey was conducted as a one round exercise in the period November 5 – November 16, 2001. A reminder was sent out on November 12. However, it should be mentioned that a smaller additional set of experts (18) was included in the total population rather lately (November 13), meaning that they received exclusively the first invitation to participate in the survey.

The initial population of the survey was 329 experts, of whom 141 were identified by IZT, 53 by COGEN, 50 by ECN, 15 by Lars Nielsen, and 70 by Risoe National Laboratory. Furthermore, experts were invited to forward the invitation to other relevant experts. We do not know the number of this nominated population. All respondents received an e-mail invitation to participate in the survey. 32 out of the 329 were returned due to unknown or unidentified addresses, making a population of 297. A total number of 66 experts filled out the questionnaire. This makes a response rate of 22%. Compared to other international technology foresight exercises, the response rate is less than the British Delphi in 1995 with approximately 31% response rate, but more than the Danish sensor technology foresight in 2001 made by Risoe National Laboratory, making a response rate of 16%.

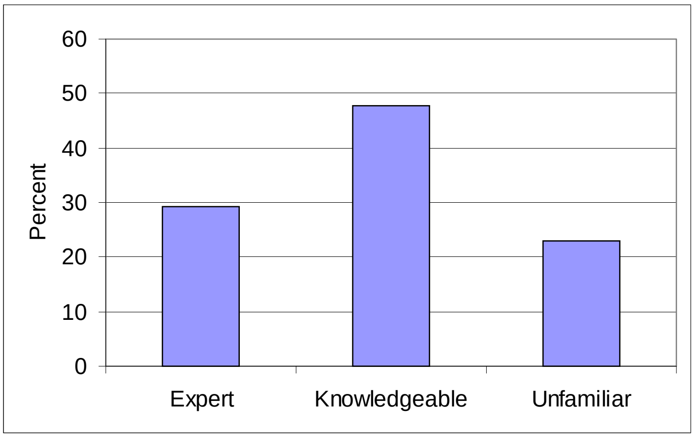
The following outlines the profile of the responding population, as captured by background information:

- Respondents work primarily in Denmark (29%), 14% work in Spain, 11% work in the Netherlands, and 8% in the United Kingdom. The remaining respondents work in Italy, Germany, Portugal, Finland, France, Luxembourg, Slovenia, Switzerland, and the USA. Approximately 20% have not specified in which country they primarily work.

- The majority of the respondents work first and foremost in academic research (27%), and in corporate strategy for research and technology (20%). Some work in public administration and planning (14%), and marketing/business management (11%). Only 5% work in production/operations. Respondents also work in consultancy, trade union, business association, and promotion of renewable energy sources among the general public. 14% have not answered the question.

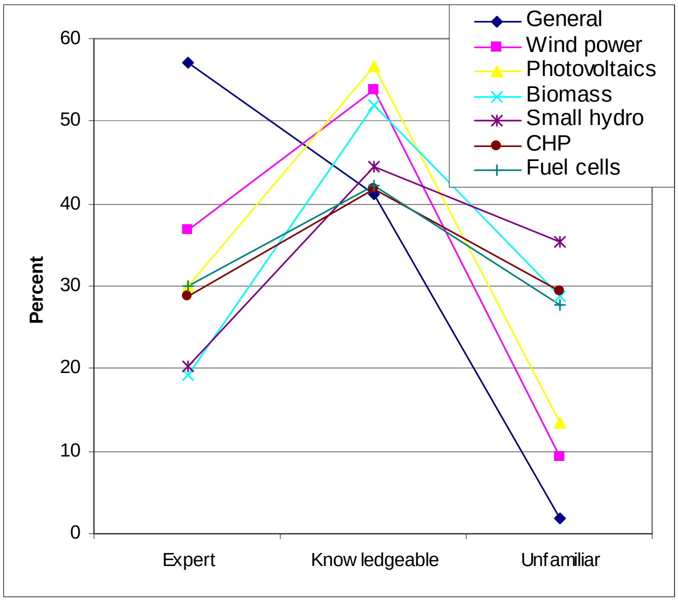
Generally, respondents are expert or knowledgeable about the technological topics highlighted in the questionnaire as it appears from the figure below.

Figure 1: Level of expertise



In particular, respondents consider themselves expert or knowledgeable within wind energy (76%) and photovoltaics (70%), and to a lesser degree within biomass (58%), CHP (56%), fuel cells (55%), and small hydro plants (49%). For details see the figure below.

Figure 2: Expertise according to energy type



General remarks from individual respondents emphasise that the questions are designed to get the political right answer and that the questions on the beneficial impact of the topic on environment and cost of energy is difficult to understand. One respondent, moreover, points to the error in statement No. 18 (20-400 MW instead of 20-400 kW).

General framework topics important for decentralised energy generation in the EU up to 2020

Respondents were asked to assess a number of framework topics and their impact on the future decentralised energy generation in the EU up to 2020. In the table below, the results are shown.

Highly beneficial and beneficial impact is in particular expected from global environmental concern (82%), easy and transparent grid access for DGs (77%), and renewables prioritised in power dispatch (71%), but also from EU support mechanisms (67%), local/regional environmental concern (65%), regional development concern (59%), clear spatial planning provision and procedures (58%), and national security of supply (55%). The highly beneficial and beneficial impact is less from topics such as robust energy systems (47%), full EU liberalisation of the energy market (39%), and large European market players in electricity industry (20%).

Table 1: Impact of topics on decentral energy generation in the EU. In percentage.

	Highly beneficial	Beneficial	Neutral	Adverse	Highly adverse	N.A.
Global environmental concern (green house gases)	44	38	5			14
Local/regional environmental concern	21	44	15	6		14
Easy and transparent grid access for DGs	41	36	9			14
Renewables prioritised in power dispatch	39	32	12	3		14
Robust energy system	20	27	26	9		18
National security of supply	21	33	20	11		15
Clear spatial planning provision and procedures	11	47	23	5		15
Regional development concern	8	52	24			17
Full EU liberalisation of the energy market	9	30	15	27	3	15
Large European market players in electricity industry	6	14	26	27	12	15
EU support mechanisms for DGs	32	35	15	3		15

Neutral impact is largest from topics such as robust energy systems (26%), large European market players in electricity industry (26%), regional development concern (24%), and clear spatial planning provision and procedures (23%).

Adverse or highly adverse impact is outspoken from topics such as large European market players in electricity industry (39%) and full EU liberalisation of the energy market (30%). Some adverse impact is also expected by the topic of national security of supply (11%) and robust energy system (9%).

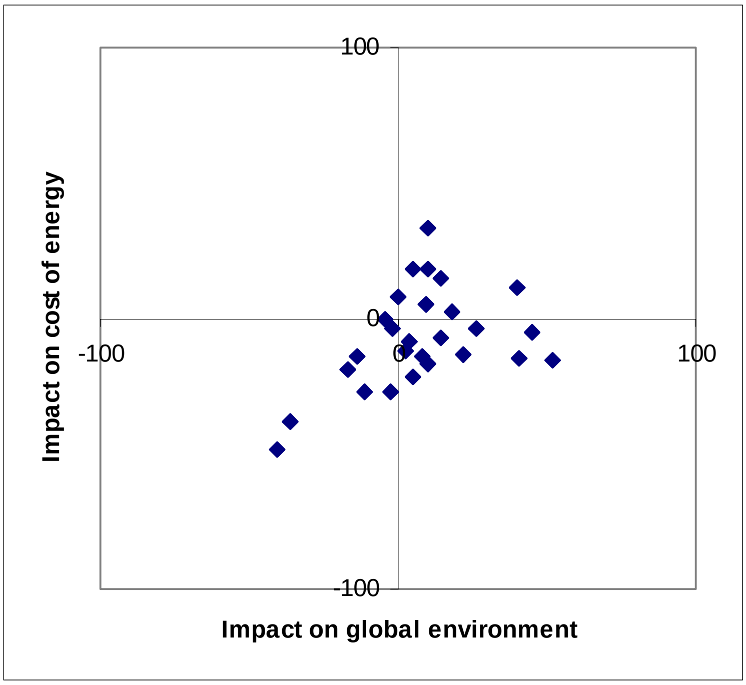
Summing up, respondents tend to disagree on topics such as full EU liberalisation of the energy market, large European market players in the electricity industry, national security of supply, and robust energy systems. On the contrary, they tend to agree on global environmental concern, easy and transparent grid access, and regional development concern.

Ranking of Topics

The ranking of the 27 statements on the future development of decentralised energy generation is based on the combined index of impact on global environment (CO2) and impact on cost of energy production. Based on expert and knowledgeable responses to each topic, calculations have been based on total numbers of respondents and weighted values of 100 (high), 0 (medium), and –100 (Low), respectively).

The combined index of global environmental impact and cost production impact is illustrated in the figure below.

Figure 3: Combined index of global environmental impact and cost production impact



While the top topics are located in Quadrant I (upper right), attention should also be given to topics in Quadrant II (upper left) as these represent high expectations to cost production, but with large unsolved environmental challenges. Topics in Quadrant IV (lower right) are also interesting as they represent an environmental push looking for cost production reductions. Quadrant III (lower left) is not interesting having low expectations to beneficial impact on both global environmental and cost production.

The top ten topics selected by the combined index are presented below.

Table **2** outlines the beneficial impact on global environment, cost production, as well as the combined index together with time of occurrence. The top ten topics have a combined index higher than or equal to 10.

The top ten topics include all decentralised energy forms, except for CHP and small hydro plants. Eight out of ten topics are expected to be realised in the period 2011-2020 while the remaining two are expected to be realised after 2020. Some topics may be expected to have beneficial impact on the global environment, but not to have a beneficial impact on cost of energy (No. 26, No. 2, and No. 1). A more balanced view may be observed on topics on photovoltaics (No. 9 and No. 8).

Table 2: Characteristics of top ten topics

Rank	No.	Statement	E index	C index	E&C index	Time of occurrence
1	3	50% cost reduction of wind produced electricity relative to 2001	40	12	26	2011-2020 (50%)
2	7	5% of Europe's electricity comes from photovoltaics	10	33	22	After 2020 (56%)
3	26	30% of fuel cell fuels in EU are derived from renewable sources	45	-5	20	After 2020 (63%)
4	2	10% of Europe's electricity comes from wind power	52	-16	18	2011-2020 (44%)
5	9	Wide spread use of photovoltaics integrated into roof tiles	15	15	15	2011-2020 (39%)
6	8	50% cost reduction of electricity from photovoltaics relative to 2001	10	18	14	2011-2020 (50)
7	1	10% of EU's power demand is covered by energy from renewable sources	40	-15	13	2011-2020 (43%)
8	25	75% cost reduction produced by stationary fuel cells relative to 2001	5	18	12	2011-2020 (42%)
9	5	More than one-third of wind turbine capacity in EU comes from offshore sites	27	-4	11	2011-2020 (58%)
10	10	20% of EU's electricity is based on biomass	18	2	10	2011-2020 (35%)

When looking at the top ten and barriers for their realisation in the table below, it is observed that lack of R&D resources is ranked as the highest barrier for half of the topics (No. 3, No. 32, No. 26, No. 8, and No. 25). Spatial planning is the most important barrier for topics on wind energy (No. 2 and No. 5), while lack of support mechanisms is highlighted for divergent topics (No. 9, No. 1, and No. 10).

Table 3: Top ten and barriers. In percentage.

Rank	No.	Statement	Spatial planning	Inadequate standards	Lack of R&D fund.	Insufficient edu./skills	Lack of supp. mech.	Lack of public info.	Other
1	3	50% cost reduction of wind produced electricity relative to 2001	18	12	27	7	24	4	8
2	7	5% of Europe's electricity comes from photovoltaics	8	11	32	4	29	11	6
3	26	30% of fuel cell fuels in EU are derived from renewable sources	10	12	36	7	27	5	2
4	2	10% of Europe's electricity comes from wind power	37	4	12	4	26	13	4
5	9	Wide spread use of photovoltaics integrated into roof tiles	14	18	16	9	25	15	3

6	8	50% cost reduction of electricity from photo-voltaics relative to 2001	3	14	40	3	27	5	7
7	1	10% of EU's power demand is covered by energy from renewable sources	16	16	13	9	27	12	7
8	25	75% cost reduction produced by stationary fuel cells relative to 2001	8	11	42	7	23	4	4
9	5	More than one-third of wind turbine capacity in EU comes from offshore sites	28	11	18	5	4	4	9
10	10	20% of EU's electricity is based on biomass	20	8	21	10	24	8	8

The higher middle list comprises topics, following the top ten topics. The topics have an index lower than 10 and higher than or equal to zero.

Table 4: Higher middle list

Rank	No.	Statement	E index	C index	E&C in-dex
11	6	Development of a new revolutionary and competitive wind turbine concept	10	5	7
12	22	Widespread use of domestic and commercial fuel cell units	22	-13	4
13	23	CHP fuel cell units will reach an expected life time of more than 40,000 working hours	0	8	4
14	24	10% of Europe's domestic power demand is covered by fuel cells located in domestic houses	15	-7	4

The lower middle list contains topics with an index lower than zero and higher than or equal to –10.

Table 5: Lower middle list

Rank	No.	Statement	E index	C index	E&C in-dex
15	17	10% of private households in EU have micro CHP units installed	-4	0	-2
16	4	Practical use of wind turbines at a rated capacity of 10 MW	4	-8	-2
17	27	The share of fuel cells used only for power generation exceeds 20% in EU	8	-14	-3
18	11	50% cost reduction of electricity from bio-mass relative to 2001	-2	-4	-3
19	18	Micro and mini CHP (20-400 kW) accounts for 10% of EU's total electricity production from CHP schemes	10	-17	-3
20	13	Widespread use of biomass gasification tech-nologies in EU	2	-12	-5
21	21	The average energy efficiency of micro and mini CHP schemes will be greater than 80%.	5	-22	-8

The bottom list contains topics with an index lower than –10.

Table 6: Bottom list

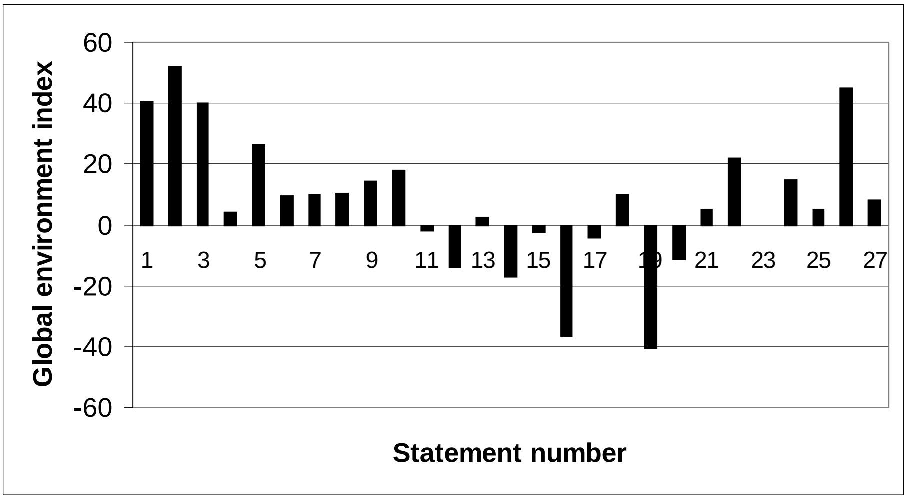
Rank	No.	Statement	E index	C index	E&C index
22	12	Energy crops cover more than half of the total biomass use in EU	-14	-14	-14
23	15	The capacity of small hydro power generation (<10MW) will be increased by 10% (compared to 2001)	-2	-27	-15
24	14	Environmental concern about energy crop growth limits the use of biomass	-17	-19	-18
25	20	The number of new installations of micro and mini turbine will peak.	-11	-27	-19
26	16	Growing environmental concern stops the installation of small hydro power generators	-36	-38	-37
27	19	The capacity of new installed micro turbines for CHP applications below 100 kW will exceed the capacity of new installed recuperating engines below 100 kW.	-41	-49	-45

Environment and cost of energy

Beneficial impact on global environment

In Figure 4, the topics are presented according to the average index of beneficial impact on global environment. It is calculated based on the total numbers of respondents and weighted values of 100 (High), 0 (Medium), and –100 (Low), respectively.

Figure 4: Index of beneficial impact on global environment



The top ten of beneficial impact on global environment is presented in the table below. From the list it may be observed that all decentralised energy generation technologies are included in the top ten list except for CHP and small hydropower generation. Wind power topics are at the very top, focusing on the energy coverage of EU's electricity (No. 2), cost reduction of wind produced electricity (No. 3), and offshore wind farms (No. 27). The second highest topic regards renewable sources for fuel cells (No. 26), and the third topic regards EU's power demand covered by renewable sources (No.1). The widespread use of domestic and commercial fuel cells (N0. 22) as well as domestic demand covered by fuel cells in domestic house (No. 24) are ranked number six and eight, respectively. Electricity based on biomass (No. 10) is ranked number seven, and photovoltaics (No. 9 and No. 8) number nine and ten.

Table 7: Top ten of beneficial impact on global environment

Rank	No.	Statement	E index
1	2	10% of Europe's electricity comes from wind power	52
2	26	30% of fuel cell fuels in EU are derived from renewable sources	45
3	1	10% of Europe's power demand is covered by energy from renewable sources	40
4	3	50% cost reduction of wind produced electricity relative to 2001	40
5	5	More than one-third of wind turbine capacity in Europe comes from offshore sites	27
6	22	Widespread use of domestic and commercial fuel cell units	22
7	10	20% of EU's electricity is based on biomass	18
8	24	10% of Europe's domestic power demand is covered by fuel cells located in domestic houses	15
9	9	Wide spread use of photovoltaics integrated into roof tiles	15
10	8	50% cost reduction of electricity from photovoltaics relative to 2001	10

The bottom list comprises topics with an average index below zero.

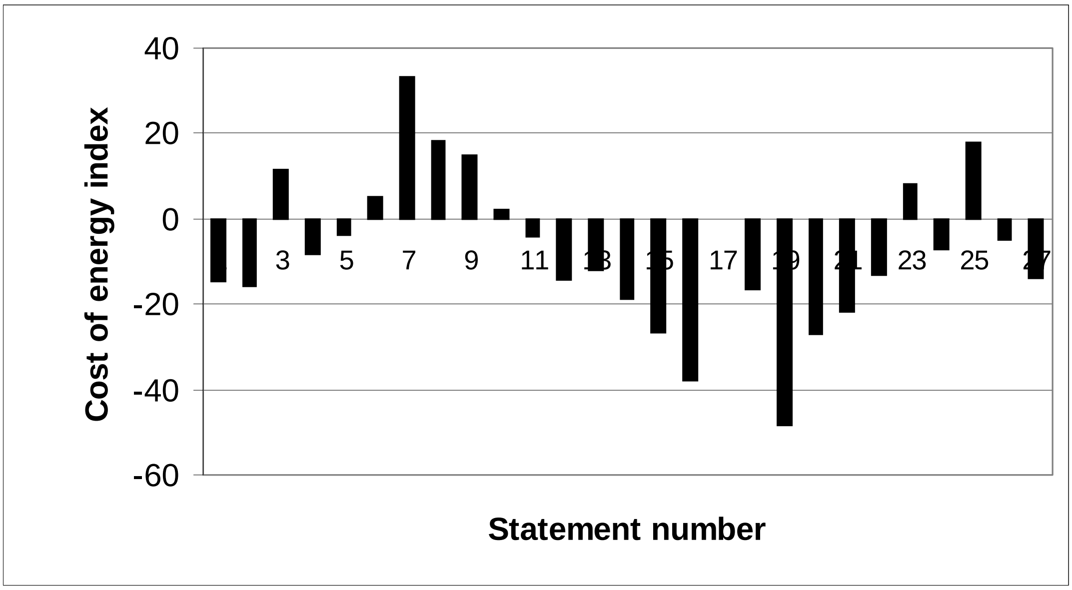
Table 8: Bottom list of beneficial impact on global environment

Rank	No.	Statement	E index
20	11	50% cost reduction of electricity from biomass relative to 2001	-2
21	15	The capacity of small hydro power generation (<10MW) will be increased by 10% (compared to 2001)	-2
22	17	10% of private households in EU have micro CHP units installed	-4
23	20	The number of new installations of micro and mini turbine will peak	-11
24	12	Energy crops cover more than half of the total biomass use in EU	-14
25	14	Environmental concern about energy crop growth limits the use of biomass	-17
26	16	Growing environmental concern stops the installation of small hydro power generators	-36
27	19	The capacity of new installed micro turbines for CHP applications below 100 kW will exceed the capacity of new installed recuperating engines below 100 kW	-41

The beneficial impact on cost of energy production

In the figure below, the topics are presented according to the average index of beneficial impact on cost of energy production. It is calculated based on the total numbers of respondents and weighted values of 100 (High), 0 (Medium), and –100 (Low), respectively.

Figure 5: Index of beneficial impact on cost of energy production



The top ten [nine] list comprises the three topics on cost reduction, though differing on the total cost reduction. Topics on photovoltaics (no. 7 and No. 9) have high rankings, not surprisingly due to the implicit economy of scale. In the same field are topics such as fuel cells units with a 40,000 working hour (N0. 23), 20% electricity based on biomass (No. 10), and 10% private micro CHP (No. 10). The new wind turbine concept is also expected to have beneficial impact on cost of energy.

Table 9: Top ten [nine] list of beneficial impact on cost of energy

Rank	No.	Statement	C index
1	7	5% of Europe's electricity comes from photovoltaics	33
2	8	50% cost reduction of electricity from photovoltaics relative to 2001	18
3	25	75% cost reduction produced by stationary fuel cells relative to 2001	18
4	9	Wide spread use of photovoltaics integrated into roof tiles	15
5	3	50% cost reduction of wind produced electricity relative to 2001	12
6	23	CHP fuel cell units will reach an expected life time of more than 40,000 working hours	8
7	6	Development of a new revolutionary and competitive wind turbine concept	5
8	10	20% of EU's electricity is based on biomass	2
9	17	10% of private households in EU have micro CHP units installed.	0

As the remaining topics all have an index lower than zero, only the last five topics are included in the bottom list. Surface to say that the very bottom topic is No. 19 regarding CHP applications below 100 kW, just like the bottom list of the beneficial impact on global environment.

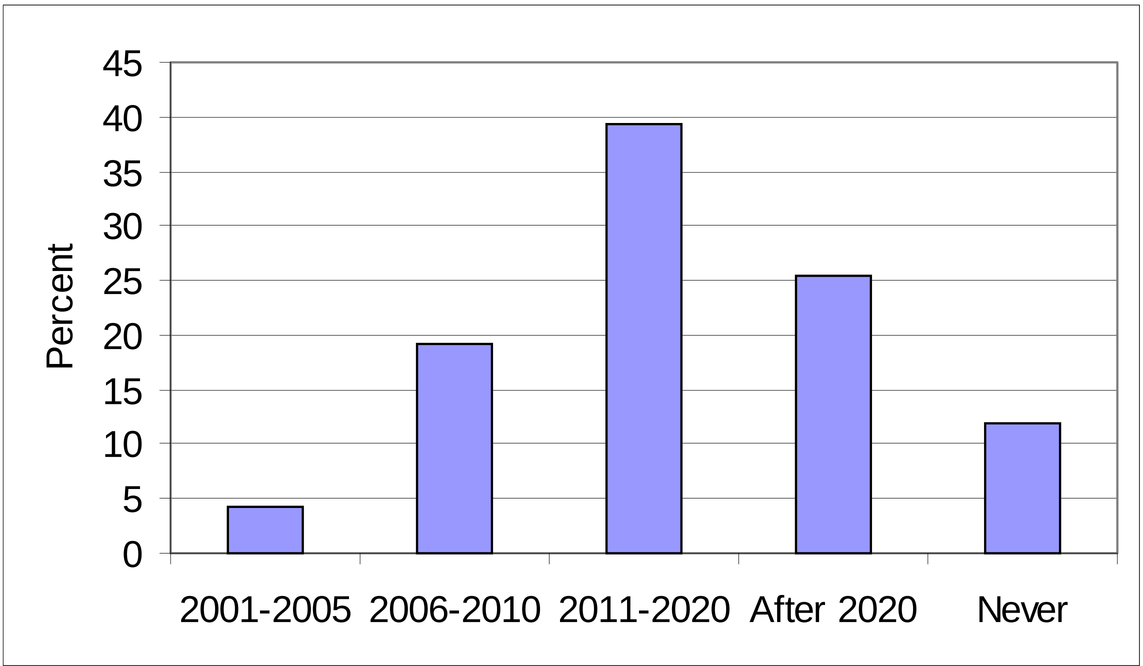
Table 10: Bottom list of beneficial impact on cost of energy

Rank	No.	Statement	C index
23	21	The average energy efficiency of micro and mini CHP schemes will be greater than 80%.	-22
24	15	The capacity of small hydropower generation (<10MW) will be increased by 10% (compared to 2001).	-27
25	20	The number of new installations of micro and mini turbine will peak.	-27
26	16	Growing environmental concern stops the installation of small hydro power generators	-38
27	19	The capacity of new installed micro turbines for CHP applications below 100 kW will exceed the capacity of new installed recuperating engines below 100 kW	-49

Period of Occurrence

The topics are expected to be realised mainly in the period 2011-2020. The figure below shows that 39% of the topics are expected to be realised in this period, 25% of the topics after 2020, 19% in the period 2006-2010, and 12% are expected never to be realised. Only 4% are expected to be realised before 2005.

Figure 6: Time of occurrence for all decentralised energy topics



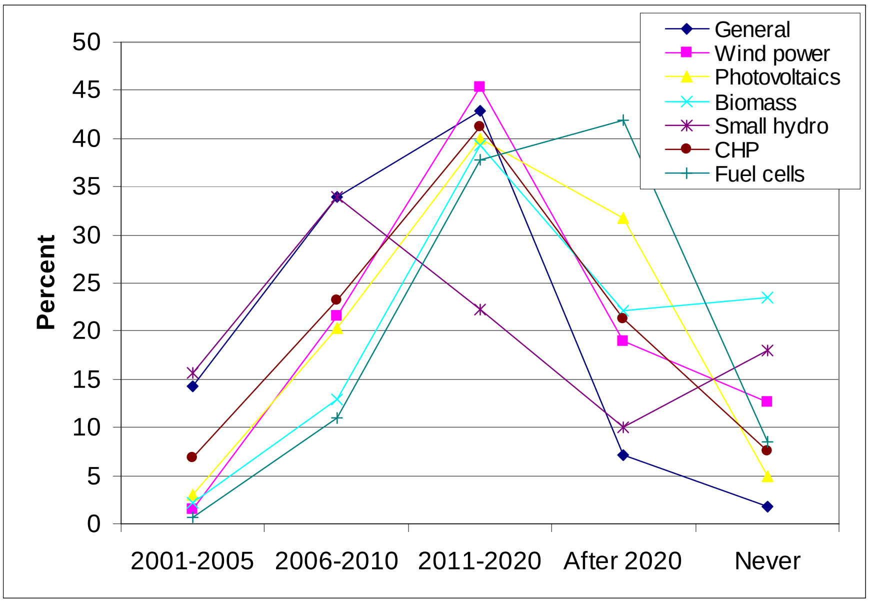
The analysis of the responses indicating that the topic will "Never" occur has been conducted on the basis that if the "Never" exceeds 15% of total responses, it is classified as significant.

Table 11: "Never" responses

No.	Statement	Never
12	Energy crops cover more than half of the total biomass use in EU	34%
10	20% of EU's electricity is based on biomass	30%
11	50% cost reduction of electricity from biomass relative to 2001	23%
14	Environmental concern about energy crop growth limits the use of biomass	23%
16	Growing environmental concern stops the installation of small hydro power generators	23%
6	Development of a new revolutionary and competitive wind turbine concept	19%
27	The share of fuel cells used only for power generation exceeds 20% in EU	18%
25	75% cost reduction produced by stationary fuel cells relative to 2001	16%

The time of occurrence for each decentralised energy type is shown in the figure below. The majority of energy types peaks in the period 2011-2020, including wind power (45%), CHP (41%), photovoltaics (40%), and biomass (39%). Fuel cells peak after 2020 (42%), while small hydro plants already peak in the period 2006-2010.

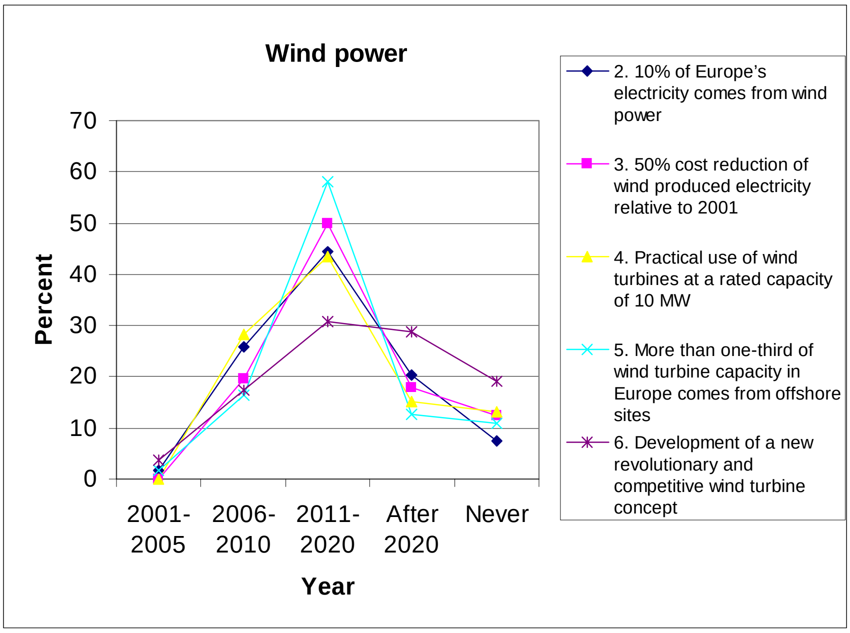
Figure 7: Time of occurrence by energy types



In the following, type occurrence by energy types is further analysed. Within each energy type, the time of occurrence is shown for single statements.

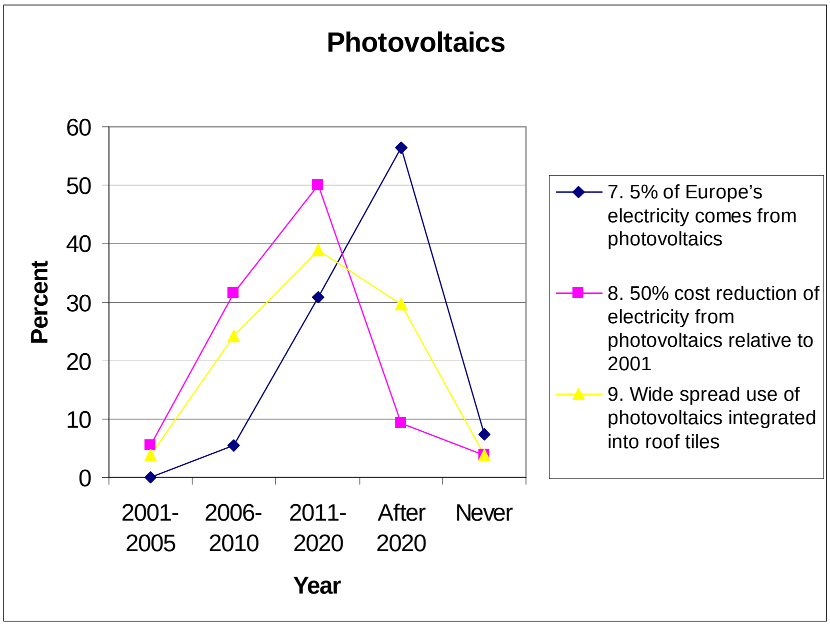
From the figure below, it can be seen that the majority of experts expect off shore wind turbines to peak in the period 2011-2020 (No. 5). More disagreement among experts is related to the development of a new revolutionary wind turbine concept (No. 6), as app. 30% expect it to be realised after 2020 and 1/5 do not expect it to be realised ever.

Figure 8: Time of occurrence for wind power



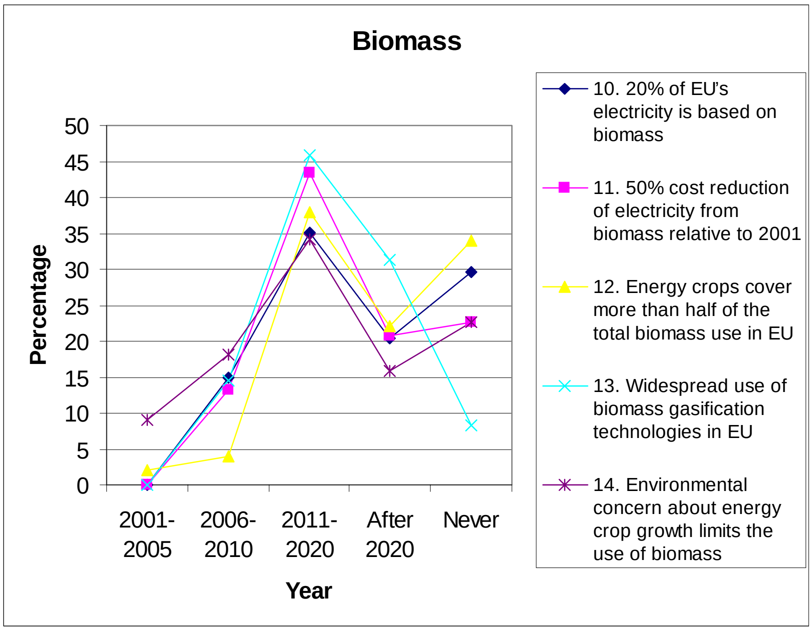
For photovoltaic the time of occurrence is shown in Figure 9. The majority of experts do not expect photovoltaics to play a larger role in the production of electricity before 2020 (No. 7). This is interesting as app. 40% of experts expect 50% cost reduction of electricity to come from photovoltaics in 2011-2020 (No. 8).

Figure 9: Time of occurrence for photovoltaic



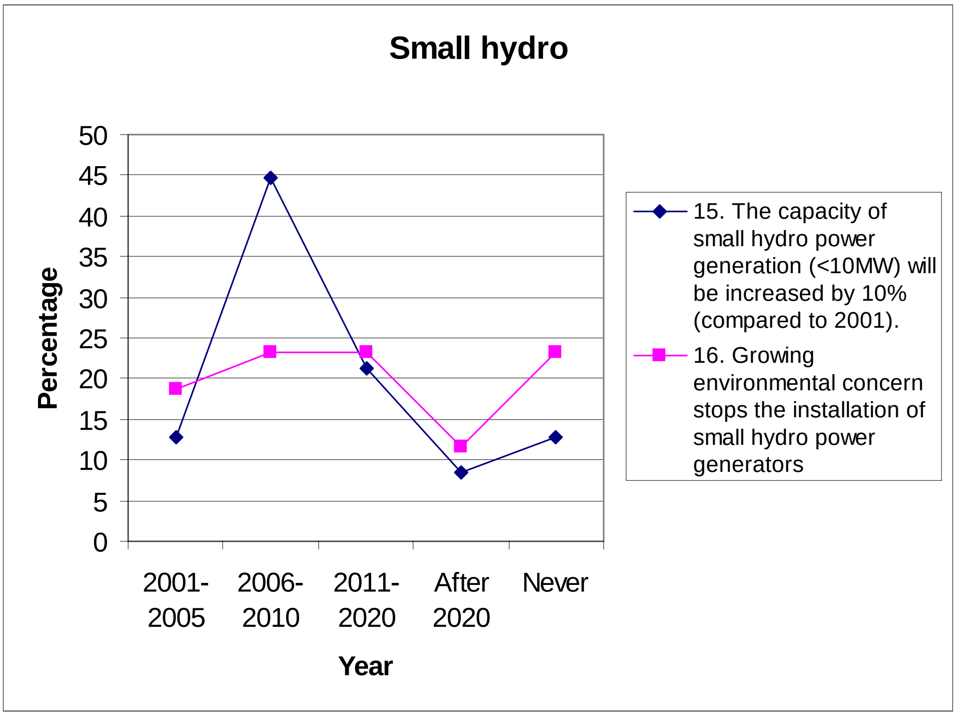
Time of occurrence for biomass showns a relatively uniform picture across statements with disagreement among expert regarding time of occurrence. Between 35-40% of experts expect the statement to be realised in the period 2011-2020, while app. 40-50% of expert expect the statements to be realised after 2020 or never.

Figure 10: Time of occurrence of biomass



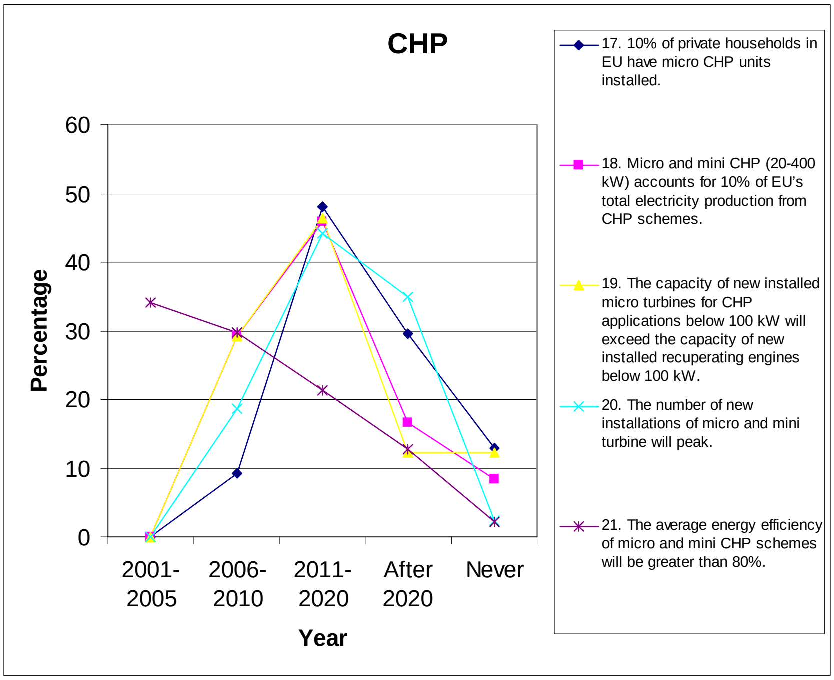
For small hydro plants, the expectation among experts is in particular high regarding a relatively rapid 10% increase in capacity of small hydro power generation (No. 15).

Figure 11: Time of occurrence of small hydro plants



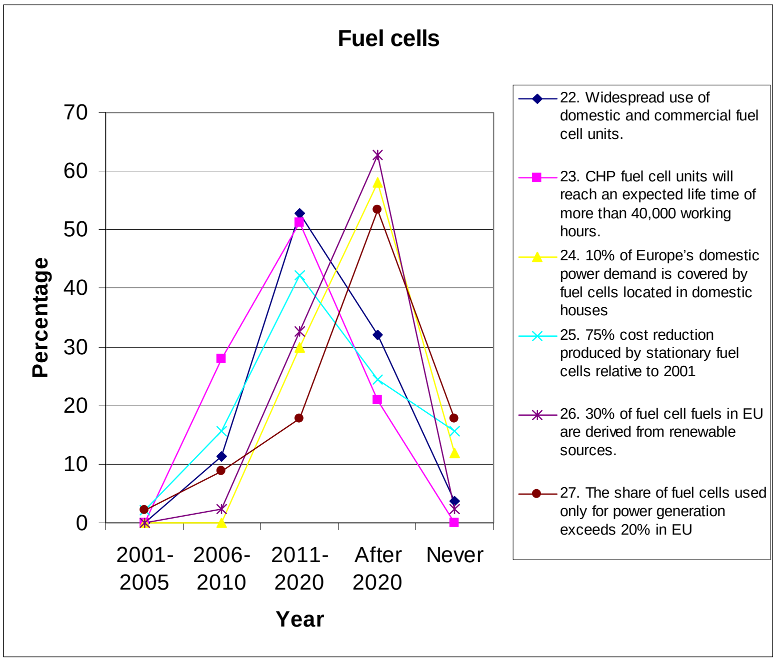
The expected time of occurrence for CHP rather uniform across the different statements except for one, with app. half of experts expecting them to be realised in the period 2011-2020. The outsider is No. 21 regarding an average energy efficiency of >80%. Here 2/3 of experts expect it to be realised in 2001-2010 (No. 21).

Figure 12: Time of occurrence of CHP



Time expectations regarding fuel cells are shown below. Expectations are relatively uniform in terms of long term, i.e. after 2011. App. half of experts expect three statements to be realised mainly in the period 2011-2020 (No. 22, 23, 25) whereas up to 60% of experts expect another three statements to be realised mainly after 2020 (No. 26, 27, 28).

Figure 13: time of occurrence of fuel cells

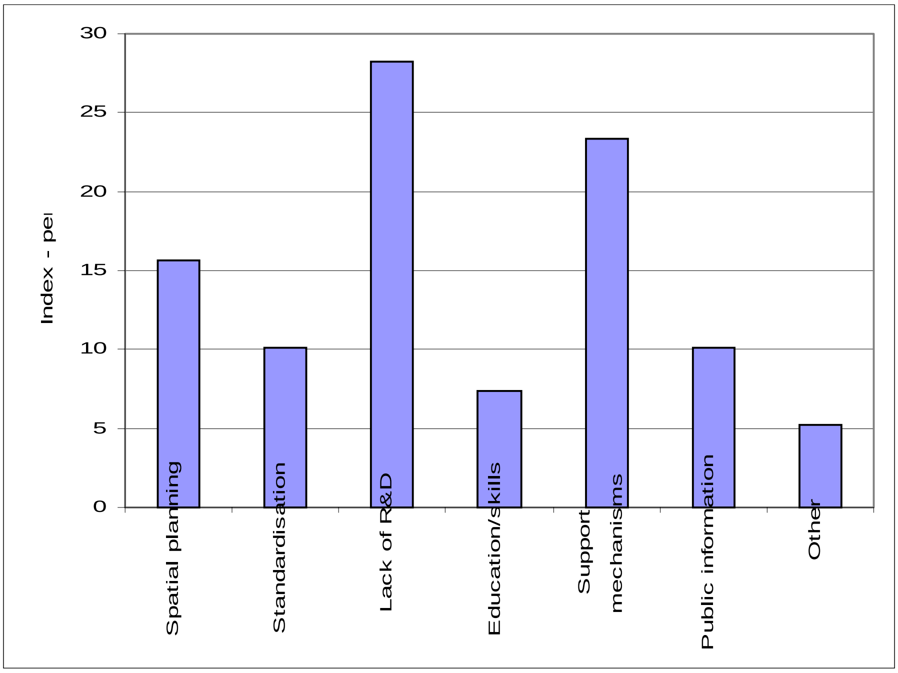


Constraints for realising the topic

The realisation of the topics may be constrained by a number of framework conditions that are central to the development of the topic.

Barriers are first and foremost limited to lack of R&D resources (28%), lack of support mechanisms (23%), and spatial planning provision and procedures (16%). Important are also standardisation (10%) and lack of public information (10%), whereas insufficient education/training skills are perceived as a barrier by only 5%.

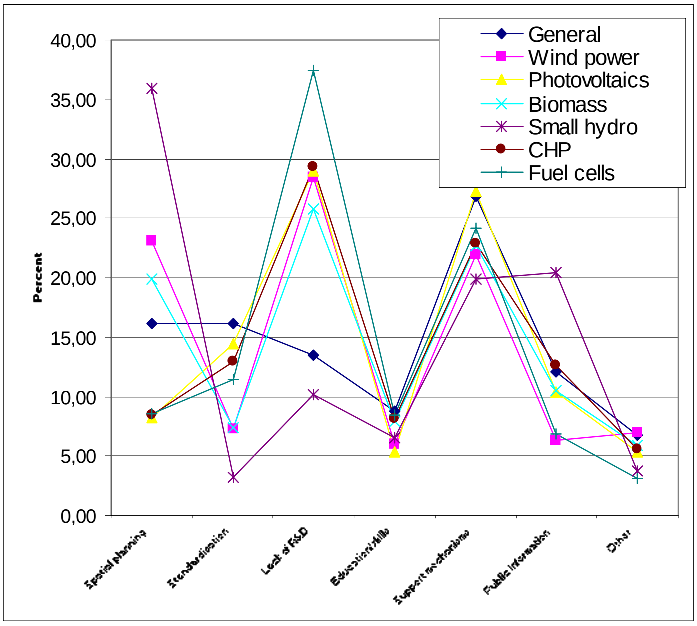
Figure 14: Barriers for realising the topics



Other framework barriers are for example ”No common EU policy” or ”Lack of political commitment” (No. 1, No. 5, No. 10). ”Lack of favourable sites” is mentioned for wind energy (No. 2, No. 3, No. 4) and small hydro plants (No. 15, No. 16). ”Lack of subsidies and implementation programmes” or ”Development of trans-sectorial and co-ordinated supply schemes” are also highlighted (No. 8, No. 11, No. 15). ”Existing national subsidies for nuclear and coal” is highlighted for topic No. 18 on micro and mini CHP percentage of EU’s CHP produced energy. ”Lack of distribution infrastructure” is highlighted for topic No. 26 on fuel cells fuel.

Fehler! Verweisquelle konnte nicht gefunden werden. shows which barriers matter for each energy type. Lack of R&D resources is perceived as a barrier for fuel cells (37%), CHP (29%), wind (28%), photovoltaics (29%), and biomass (26%). Lack of support mechanisms is high-lighted as a barrier by photovoltaics (27%), fuel cells (24%), CHP (23%), and small hydro plants (20%). Spatial planning provision and procedures is regarded a barrier for small hydro plants (36%) and wind (23%), whereas lack of public information is highlighted as a barrier for small hydro plants (20%).

Figure 15: Barriers for realising the topic by energy type



Other comments

Other comments made by respondents are:

- Determining factors to increase the DGs are: the energy price level, and the liberalisation of the energy market.
- The current trend to liberalisation of energy markets will promote the use of cheapest means of generating electricity and heat. This hinders the development and wide spread introduction of new technologies such as fuel cells and micro turbines. Active R&D and implementation support (subsidies, tax rebates etc.) are necessary to overcome this cost hurdle, in order to benefit from the inherent advantages: CO_2, NO_x, SO_2, particulate matter, VOC, -emission reduction potentials.
- DG is the model permitting all consumers to produce electricity with the technology or energy resource they can afford or prefer for social or environmental reasons. What is missing is the legislative frame, standardisation, no discrimination from the grid monopolies or the utilities. In other words, the ideology of a different electric system, decentralised.
- The electricity grid in Europe is in general not designed to handle the new demands on integrating large numbers of small. New planning tools for network integration have to be developed.
- When implementing micro and mini CHP in households and industries, it is crucial to focus on energy savings as well.
- Offshore wind should concentrate on new development (e.g. floating turbines) rather than using adapted land-turbines.