Power-to-X in Denmark

Purpose of this expert questionnaire:

The purpose of this questionnaire is to gain insights into the state-of-the-art, applications, and future challenges of the development of Power-to-X (P2X) in Denmark. It constitutes the second round of a so called "Delphi-study", which aims at quantitatively evaluating the results of the first round with a panel of leading experts. The responses will be cited in an associated paper profiling the advantages, disadvantages, challenges, and future needs for P2X in Denmark, including a literature study and insights from the experts such as you.

Questionnaire consist of two parts: SWOT factor analysis and identification of potential Niche markets as well as Regulatory framework and incentive structures.

P2X technology encompasses all technological pathways combining electrolysis technologies (alkaline, PEM, SOEC) that convert electricity into hydrogen, carbon source in form of gasification of biomass or other means of production of biogas or CO_2 capture, nitrogen source, and final conversion to methanol, methane or ammonia. Methanol and methane can be further processed to other liquid electrofuels.

For any questions or other feedback, please feel free to contact: Noémi Schneider, noemi@plan.aau.dk +45 9940 2527. Thank you for taking time to answer our questions and contribute to our research, the authors:

- Iva Ridjan Skov, Department of Planning, Aalborg University
- Noémi Schneider, Department of Planning, Aalborg University
- Alfred Posch, Institute of Systems Sciences, Innovation and Sustainability Research, University of Graz
- Gerald Schweiger, Institute for Software Technology, Graz University of Technology

AALBORG UNIVERSITY UNI GRAZ TU Graz

There are 15 questions in this survey

General questions

[]Where do you work? *

Please choose **only one** of the following:

- Research/Academia
- Energy provider/ network operator
- Public authority
- Technology producers
- Other

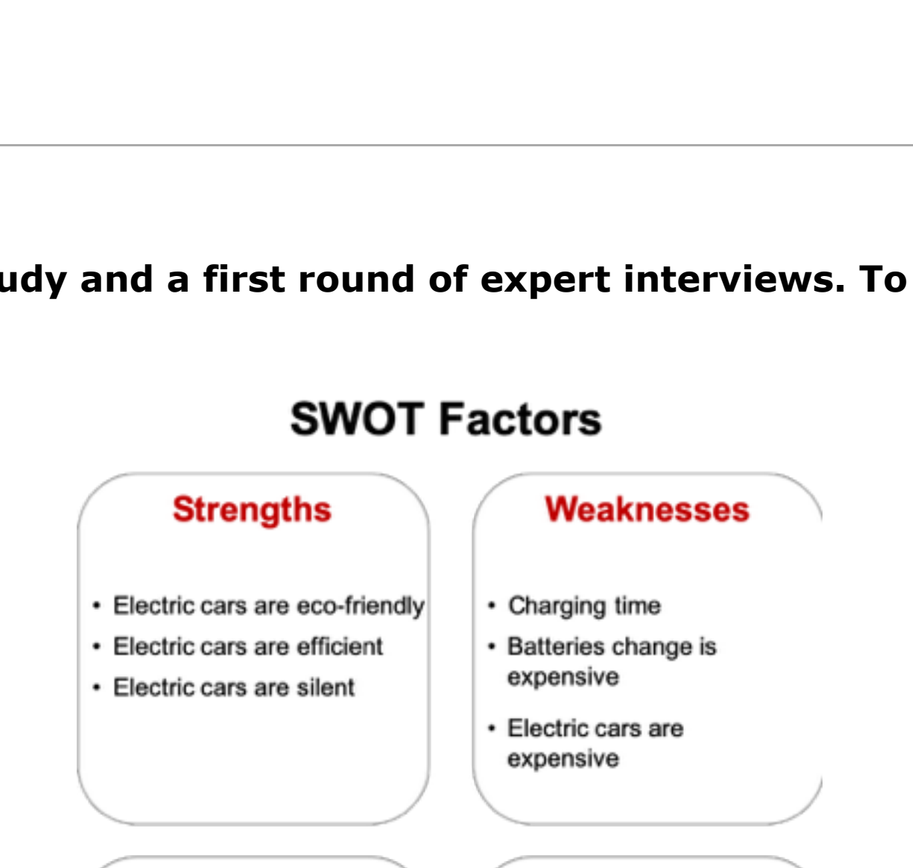
[]What is your field of expertise?

Please write your answer here:

SWOT-AHP

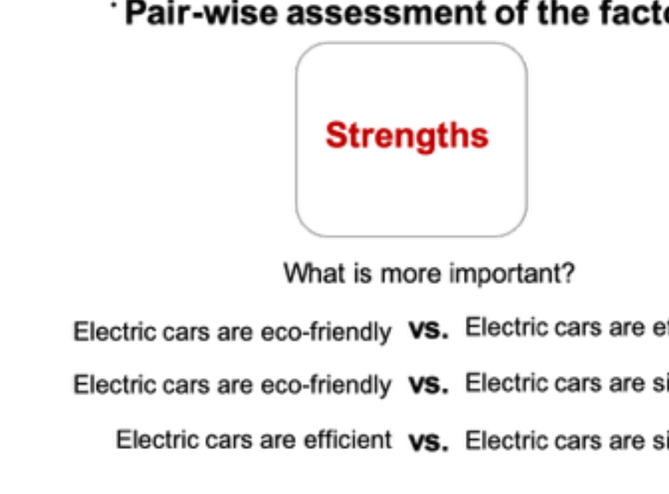
[]

The SWOT factors were identified based on an extensive literature study and a first round of expert interviews. To illustrate this, here are SWOT factors for an imaginary analysis in the field of e-mobility.



The goal of a SWOT-AHP method is to gain a better understanding of the relative importance of each factor. Therefore, in this survey you will be asked to compare and weight the respective factors in each category pairwise. Again, a dummy example in the field of e-mobility.

In a final step you will be asked to compare the four SWOT groups themselves, while bearing in mind the factors per group.



This part comprises a SWOT analysis. For each group, i.e. strengths, weaknesses, opportunities, and threats, four factors are proposed. The factors are based on the answers from previously conducted expert interviews.

Four factors are listed in pairs under each of the groups and are to be cross-compared.

We kindly ask you to compare pairs of these factors and rate their relative importance.

[]

Please **compare the pairs of factors** in the group ***Strengths*** and **rate their relative importance.**

9 = much more important; 1 = equally important

*

Please choose the appropriate response for each item:

	much more important 9	7	5	3	equally important 1	3	5	7	much more important 9	
P2X improves system flexibility										**P2X enables sector coupling**
P2X improves system flexibility										**P2X provides a large spectrum of end-products that are compatible with existing infrastructure and equipment**
P2X improves system flexibility										**P2X contributes to decarbonize parts of transport sector not suitable for direct electrification**
P2X enables sector coupling										**P2X provides a large spectrum of end-products that are compatible with existing infrastructure and equipment**
P2X enables sector coupling										**P2X contributes to decarbonize parts of transport sector not suitable for direct electrification**
P2X provides a large spectrum of end-products that are compatible with existing infrastructure and equipment										**P2X contributes to decarbonize parts of transport sector not suitable for direct electrification**

[]

Do you consider any other factor than the above as being more important? If yes, please name it:

Please write your answer here:

Comparison of Weaknesses of P2X

[]

Please **compare the pairs of factors** in the group ***Weaknesses*** and **rate their relative importance.**

9 = much more important; 1 = equally important

*

Please choose the appropriate response for each item:

	much more important 9	7	5	3	equally important 1	3	5	7	much more important 9	
P2X lacks cost competitiveness due to electricity price and electrolysis CAPEX										**P2X lacks upscaling and manufacturing production capacity**
P2X lacks cost competitiveness due to electricity price and electrolysis CAPEX										**P2X technologies have low production efficiency.**
P2X lacks cost competitiveness due to electricity price and electrolysis CAPEX										**P2X technologies are immature and have short lifetime (electrolysis)**
P2X lacks upscaling and manufacturing production capacity										**P2X technologies have low production efficiency.**
P2X lacks upscaling and manufacturing production capacity										**P2X technologies are immature and have short lifetime (electrolysis)**
P2X technologies have low production efficiency										**P2X technologies are immature and have short lifetime (electrolysis)**

[]

Do you consider any other factor than the above as being more important? If yes, please name it:

Please write your answer here:

Comparison of Opportunities of P2X

[]

Please compare the pairs of factors in the group *Opportunities* and rate their relative importance.

9 = much more important; 1 = equally important

*****

Please choose the appropriate response for each item:

	much more important 9	7	5	3	equally important 1	3	5	7	much more important 9	
The European Union ambitious climate targets support further expansion of renewable energy										**Consensus on limited biomass availability and the need to minimise its use**
The European Union ambitious climate targets support further expansion of renewable energy										**Existing district heating networks can benefit from excess heat from the P2X processes**
The European Union ambitious climate targets support further expansion of renewable energy										**Denmark is a P2X knowledge hub**
Consensus on limited biomass availability and the need to minimise its use										**Existing district heating networks can benefit from excess heat from the P2X processes**
Consensus on limited biomass availability and the need to minimise its use										**Denmark is a P2X knowledge hub**
Existing district heating networks can benefit from excess heat from the P2X processes										**Denmark is a P2X knowledge hub**

[]

Do you consider any other factor than the above as being more important? If yes, please name it:

Please write your answer here:

Comparison of Threats of P2X

[]

Please compare the pairs of factors in the group *Threats* and rate their relative importance.

9 = much more important; 1 = equally important

*****

Please choose the appropriate response for each item:

	much more important 9	7	5	3	equally important 1	3	5	7	much more important 9	
Competitive technologies are more visible and economically attractive										**Uncertainty upon fuel market readiness or support schemes**
Competitive technologies are more visible and economically attractive										**Rising electricity prices**
Competitive technologies are more visible and economically attractive										**Uncertainty on the climate agenda due to external shocks such as the COVID 19 pandemic**
Uncertainty upon fuel market readiness or support schemes										**Rising electricity prices**
Uncertainty upon fuel market readiness or support schemes										**Uncertainty on the climate agenda due to external shocks such as the COVID 19 pandemic**
Rising electricity prices										**Uncertainty on the climate agenda due to external shocks such as the COVID 19 pandemic**

[]

Do you consider any other factor than the above as being more important? If yes, please name it:

Please write your answer here:

Comparison of SWOT-categories

This part comprises a SWOT analysis. For each group, i.e. strengths, weaknesses, opportunities, and threats, four factors are proposed. The factors are based on the answers to a previous expert survey.

We kindly ask you to compare pairs of these categories as a whole and rate their relative importance for using Power-to-X.

[]

Please compare the SWOT-categories and rate their relative importance.

9 = much more important; 1 = equally important

*****

Please choose the appropriate response for each item:

	much more important 9	7	5	3	equally important 1	3	5	7	much more important 9	
Strengths										Weaknesses
Strengths										Opportunities
Strengths										Threats
Weaknesses										Opportunities
Weaknesses										Threats
Opportunities										Threats

Potential niche markets

[]To what extent do you agree to the following statements?

Please choose the appropriate response for each item:

	Entirely agree	Mostly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Mostly disagree	Entirely disagree
Hydrogen bus fleets are an essential stepping stone to push the development of P2X further							
Green hydrogen is attractive for industrial processes in existing industry							
Replacing black hydrogen with green hydrogen in refineries is a transition step to P2X fuels							
Methanol fuel cell cars are a potential niche market							
P2X should be prioritized in the chemical and pharmaceutical industry							
E-methanol is attractive for chemical industry							
Methanol is attractive for the shipping sector							
Jet fuels are a target market for electrofuels							
High purity CO from electrolysis is an interesting option for industrial purposes							
Ammonia is attractive for the shipping sector							
Small decentralised ammonia production for agricultural industry is an attractive niche market							
Ammonia combustion engines are solution for lorries, trucks and tractors							

Regulatory framework and incentive structures

[]To what extent do you agree to the following statements?

Please choose the appropriate response for each item:

	Entirely agree	Mostly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Mostly disagree	Entirely disagree
CO_2 taxation is needed to enable P2X implementation							
CO_2 price of 150€/t is sufficient to enable P2X implementation							
Blending options for P2X fuels (such as methanol and DME) have been sufficiently investigated							
Mandatory blending is needed to create competitiveness on the fuel market							
P2X fuel certification needs to be further investigated							
Mandatory low-carbon footprints of new projects are needed in order to demonstrate contribution to CO_2 reductions							
Support schemes for R&D and demonstration (flagship) projects are required							
Support schemes for P2X producers are required							
Support schemes for consumers of e-fuels are required							
Support schemes for innovation markets are needed							
There is currently enough public funding for P2X							
P2X fuels need to meet a mandatory low carbon footprint in order to contribute to CO_2 reductions							

Further information

[]

Thank you very much for your contribution!

If you want to receive the results of this study feel free to enter your E-mail address in the box below.

Please write your answer here:

Submit your survey.
Thank you for completing this survey.