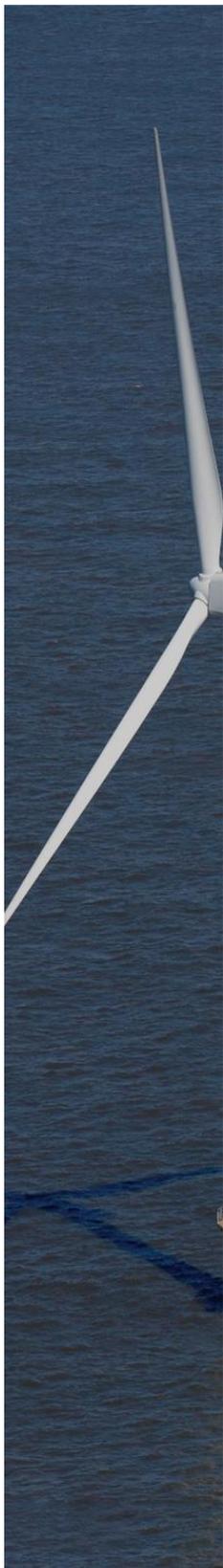


Market dialogue on hydrogen infrastructure



Market dialogue background and method



Background for the market dialogue

In the political agreement on PtX from March 2022, the Danish Government has focused on the production, sale and use of hydrogen in Denmark. The goal is for Denmark to have an installed electrolysis capacity of 4-6 GW by 2030 which will form the basis for the development of a PtX industry in Denmark. The hydrogen infrastructure is **considered** to be an important prerequisite for establishing a large-scale competitive PtX industry in Denmark, which further requires that the right framework is established. The PtX agreement allows Energinet and Evida to own and operate hydrogen infrastructure, and the market dialogue is part of the preparational work towards the final roles and responsibilities being settled.

In this connection, Evida and Energinet, with the Danish Energy Agency as an observer, have initiated a market dialogue with current and potential PtX market participants, which will be conducted in collaboration with KPMG. The purpose of the market dialogue is to establish how a hydrogen infrastructure can optimally support both producers and users of hydrogen to provide the best possible opportunities for the continued development of a PtX industry in Denmark which realises the great potential of renewable energy. The market dialogue contributes to the further planning and development of the hydrogen infrastructure of the future by, among other things, identifying the expected geographical location of future PtX plants.

Contents of market dialogue

The market dialogue aims to include all Danish hydrogen projects and market participants who have shown an interest in using or producing hydrogen and who may potentially need to use a hydrogen infrastructure, depending on how it is designed. The market dialogue thus includes potential users of hydrogen infrastructure on both the customer and production sides as well as integrated projects which includes both production and use of hydrogen in the same project. Another aim of the market dialogue has been to include both published hydrogen projects (such as those shown on Brintbranchens website) and unpublished hydrogen projects which are, for example, at an early stage and have therefore not yet published the plans for the project.

It has thus been important for the market dialogue to identify: (i) geographical location of projects and whether the respondents are on the customer side and/or on the production side, (ii) the current level of maturity of the projects, (iii) interest and need for use of a Danish pipeline hydrogen infrastructure, (iv) expectations for when investment decision and commissioning will take place, (v) expectations for volume-related production or customer needs, (vi) current barriers to realisation of the hydrogen projects, (vii) requested initiatives in relation to the establishment of a hydrogen infrastructure.

Method and procedure

The market dialogue has been conducted through a questionnaire survey and through follow-up interviews with a number of respondents from the questionnaire survey.

The questionnaire survey was conducted between 23 August and 16 September 2022. The respondents have been encouraged to respond based on the current prerequisites and assumptions in their business cases. The responses are therefore associated with an uncertainty, which some of the respondents also comment on in the free text fields of the questionnaire.

In addition to the questionnaire survey, KPMG has conducted 13 interviews with companies that have participated in the market dialogue. The interviews were used to gain more in-depth insight into why the market participants have responded as they have, and how risks, critical project elements, barriers etc. are reflected in the various hydrogen projects.

The market dialogue has involved broad participation from projects at all project stages

The market survey resulted in responses from 70 Danish hydrogen projects.

The survey is based on responses from 70 hydrogen projects in Denmark at various project stages from a total of 28 companies. In the interviews, several participants explain that they are considering additional projects, which could increase the total number of projects to about 90. By comparison, the first market dialogue, conducted by Energinet and the Danish Energy Agency in November 2021, included 32 projects.

22 of the projects are within the *hydrogen producers* category, which are projects that solely produce hydrogen in electrolysis plants, that is sold and used by others.

15 of the projects are in the *hydrogen users* category, which are projects that solely use hydrogen (produced by others), primarily for production of e-fuels.

33 of the projects are in the *integrated projects* category, which are projects that produce hydrogen in an electrolysis plant and use the hydrogen in another process. These projects consist of two project types: biogas plants, which are to use hydrogen to produce e-methane, and e-fuels producers.

Approx. 90 per cent of the projects state that they are at the feasibility stage or earlier stages – knowledge of the hydrogen infrastructure is mentioned as the element of greatest uncertainty in relation to the further investment decision.

62 out of the 70 projects state that they are at the feasibility stage or earlier stages, and only 8 projects state that they are preparing the final investment decision or are establishing the project. The eight projects in the later project stages are distributed across the different project categories, i.e. producers, users and integrated projects. The projects in the later project stages have a relatively small volume relative to the projects in the early project stages.

The market participants mention lack of knowledge regarding the location and commissioning of the hydrogen infrastructure as the most significant parameter of uncertainty, as the hydrogen infrastructure affects the design of the projects, potential approaches to greater demand, storage, flexibility etc.

Figure 1. Distribution of number of projects

(Number of projects that have filled in the questionnaire, broken down by category)

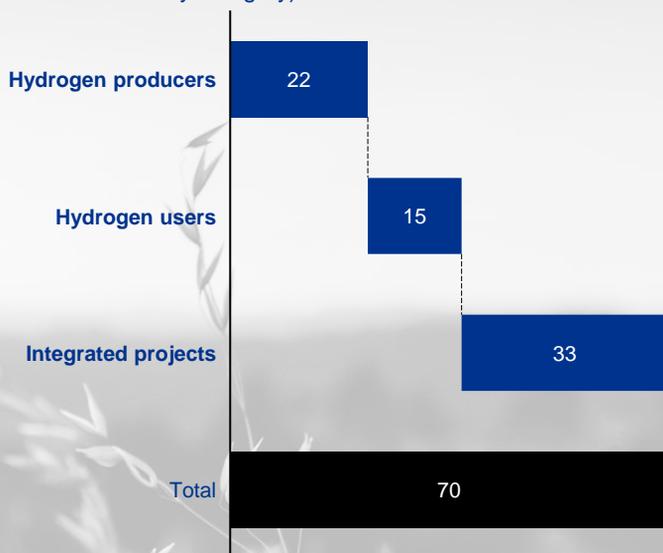
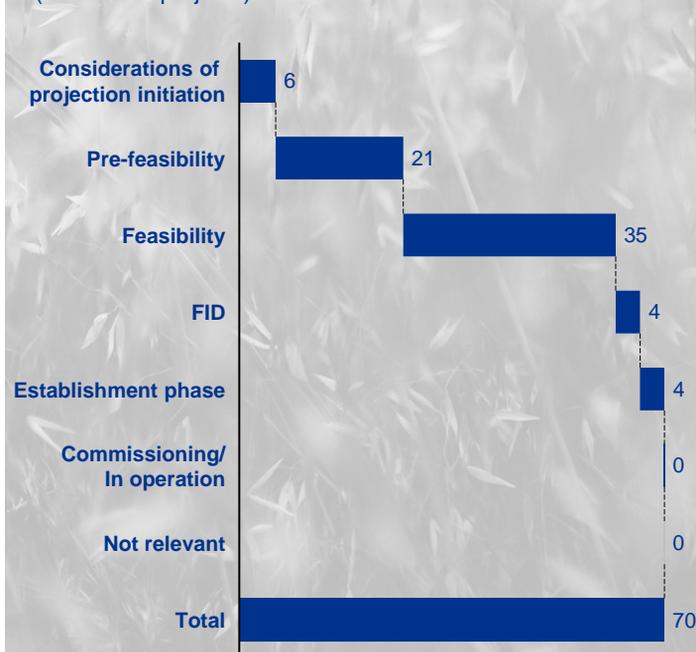


Figure 2. Current stages of the projects

(Number of projects)



Hydrogen production is expected to increase heavily and significantly exceed the use

The market participants expect hydrogen production to be significantly higher than hydrogen usage in Denmark

Based on the participants' responses in the questionnaire survey, Denmark is expected to produce approx. 1.4 million tonnes of hydrogen in 2030 and almost 1.8 million tonnes of hydrogen in 2040. This is 2.5 times more than the participants specify that they will use during the same period, equal to between 0.9 million and 1.1 million tonnes more hydrogen produced than used. A number of the large production projects are expected to become operational in 2027, when production is expected to increase heavily.

In the short term in 2025, the responses show that usage is expected to be approx. 185,000 tonnes, while production is expected to be around 150,000 tonnes. Approx. 40 per cent of the use in 2025 is expected to come from projects that are self-sufficient; i.e. projects that themselves produce the hydrogen they will use.

If the projects announced by the market participants are realised, the total Danish electrolysis capacity will exceed 14 GW in 2030.

The market participants' current plans provide for a capacity of more than 14 GW for electrolysis plants by 2030 and up to 21 GW in 2040, provided that all projects are completed as stated in the market dialogue.

Projects that are currently in the feasibility, FID or establishment phase are expected to amount to 5.9 GW in 2030. 59 per cent of the expected electrolysis capacity in 2030 thus consists of projects in early project stages (pre-feasibility and considerations of project initiation).

The schedules for commissioning are regarded as optimistic by several market participants and will depend on a number of factors, including the rate of expansion of renewable energy.

Figure 3. Expected hydrogen production and usage

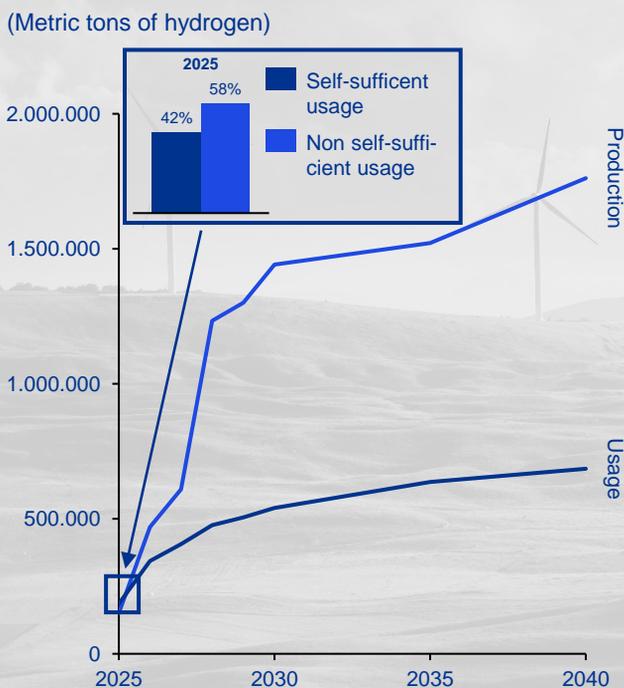
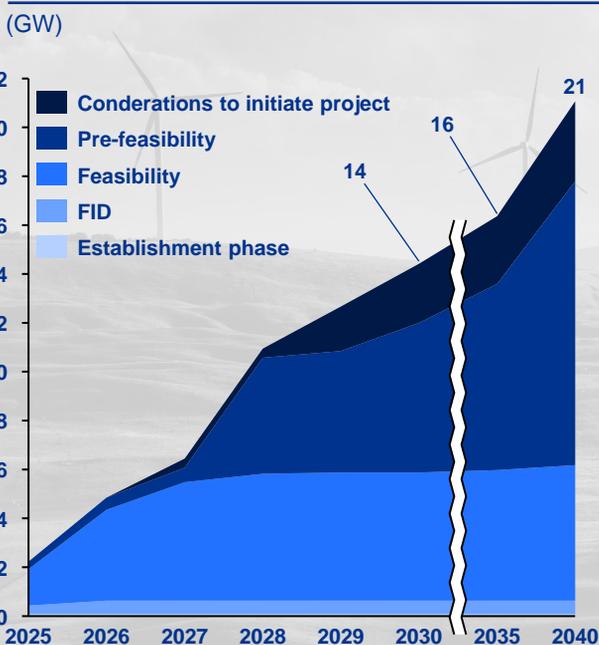


Figure 4. Expected development in electrolysis capacity



The market participants expect the highest hydrogen production and consumption west of the Great Belt

The market participants expect that approx. 69 per cent of hydrogen production by 2030 will take place west of the Great Belt in DK1¹. Approximately one third of the total hydrogen production in 2030 is currently expected to take place in and around Esbjerg in the Region of Southern Denmark and Bornholm in the Capital Region of Denmark

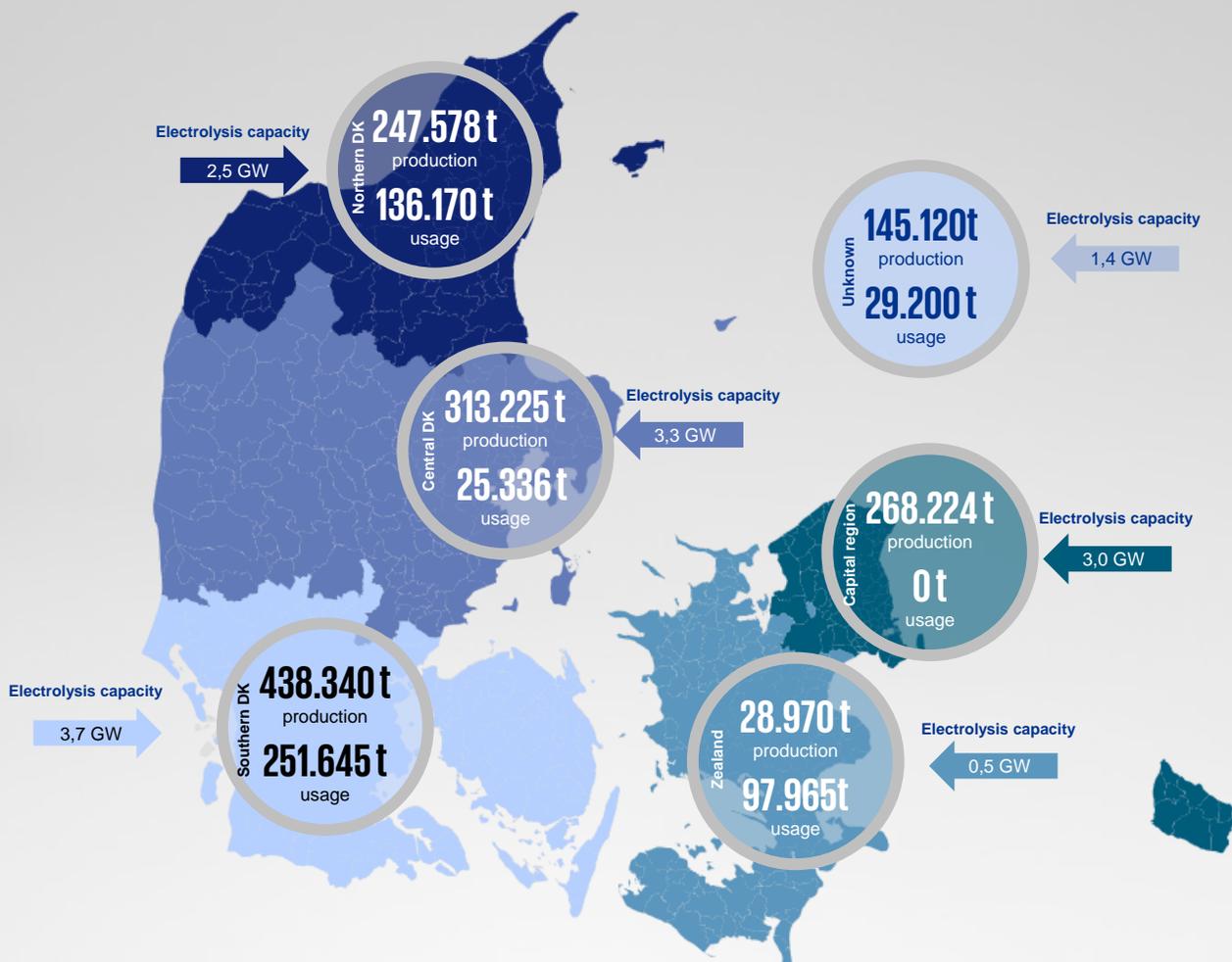
The consumption is also expected to be primarily in DK1 with 76 per cent in 2030, while 18 per cent is expected to be in DK2. Here, one of the two major consumption sites on Zealand states that it does not have a need for hydrogen infrastructure.

A few projects state that they still do not know the location of their project, or that their projects are spread out across several regions.

¹ Denmark is divided into two bidding zones. DK1 covers Funen & Jutland, and DK2 covers Zealand and Bornholm.

Figure 5. Expected geographic distribution, hydrogen production and usage in 2030

(Total hydrogen production and hydrogen usage in metric ton and electrolysis capacity)



A hydrogen infrastructure significantly strengthens the business case of the projects

The business cases of the projects are significantly strengthened by a hydrogen infrastructure in Denmark

Approx. 96 per cent of all the projects state that they need hydrogen infrastructure. The producers' business cases tend to rely more on a hydrogen infrastructure than the consumers' business cases. For just under 95 per cent of the expected volumes produced in 2030, the producers state that hydrogen infrastructure is indispensable or strengthens their business case significantly, while the corresponding figure for the users is 70 per cent. In addition, only a few user projects will completely give up using hydrogen without an infrastructure as opposed to the production projects.

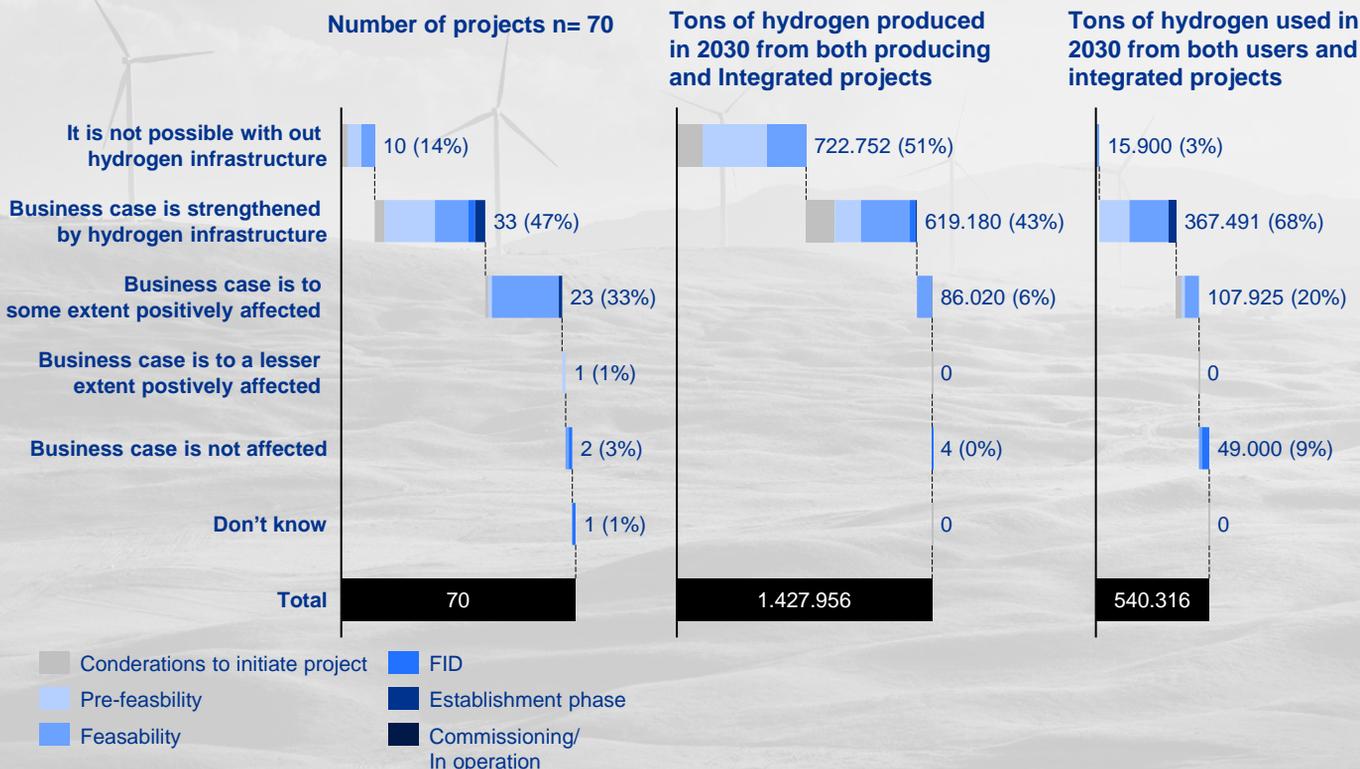
Half the expected hydrogen production in 2030 is not assessed to be realised without hydrogen infrastructure

Around one in seven projects state that their project cannot be realised without a hydrogen infrastructure. Particularly the large production projects have a great need for the infrastructure, and half the expected hydrogen production in 2030 is therefore not expected to be feasible without an infrastructure.

Hydrogen infrastructure is of greatest importance to projects in early project stages

The questionnaire survey also shows a minor tendency towards the business case for projects in the late project stages being less affected than projects in early project stages. The reason for this may be twofold: firstly the more mature projects, in which an investment decision has been made, have assumed that a hydrogen infrastructure will not be ready for their project in the short term, and secondly the advanced projects are on a smaller scale and can therefore better handle the volumes.

Figure 6. The projects' evaluation of the importance of hydrogen infrastructure



Hydrogen-producing projects expect to sell hydrogen both in Denmark and abroad

The market dialogue indicates a need for establishment of a hydrogen infrastructure for sales both in Denmark and abroad.

In the following, there is focus on sales opportunities for the projects that exclusively produce hydrogen. One reason for this focus is that more hydrogen is expected to be produced than the volume used in Denmark. Another reason is that the integrated projects mostly produce hydrogen for their own consumption.

The projects aimed exclusively at producing hydrogen are looking at sales opportunities for their hydrogen in both Denmark and abroad. As shown in Figure 7, the 22 pure production projects have stated the expected sales of their hydrogen in Denmark and abroad, respectively. As the overview shows, the projects expect to generate capacity both in Denmark and abroad, primarily through pipeline infrastructure. Therefore, both the Danish hydrogen infrastructure and an infrastructure connected to other countries are of central importance to these projects.

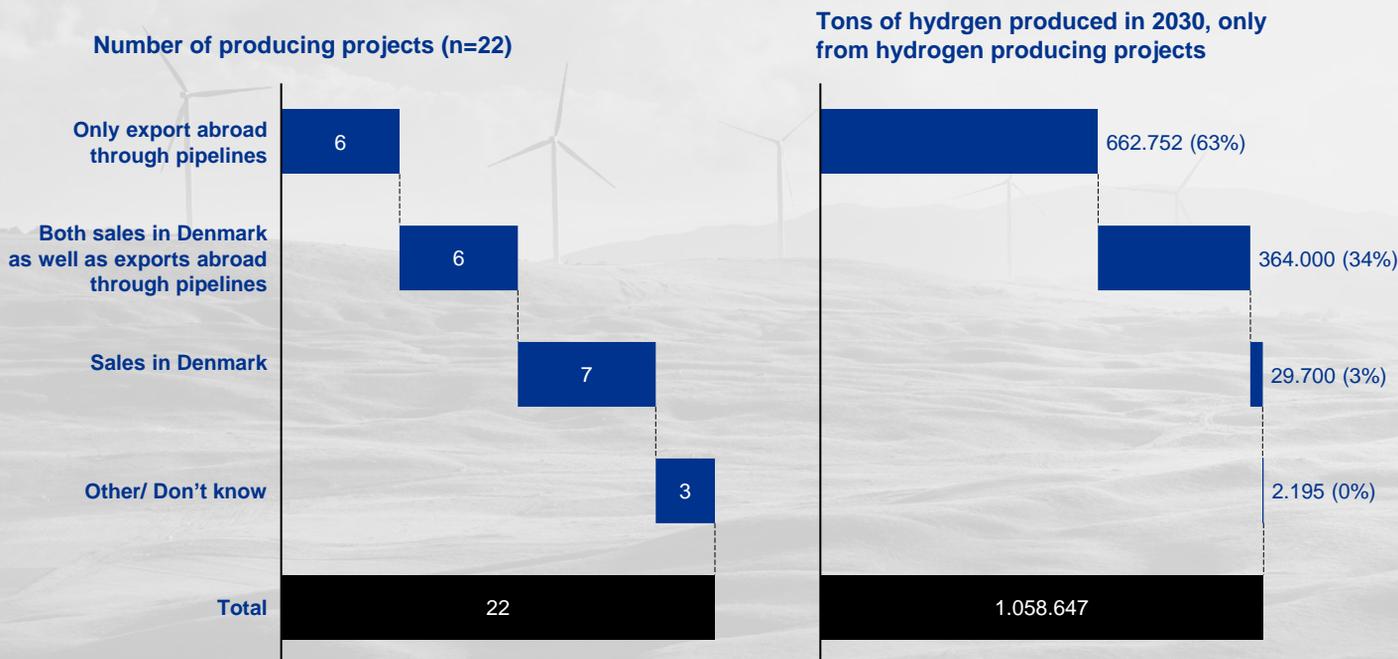
Particularly the largest hydrogen-producing projects see export opportunities

The eight largest production projects (with an electrolysis capacity of +1 GW) all expect to export hydrogen to other countries. 5 out of 8 projects expect solely to sell hydrogen to other countries, while the remaining 3 expect to sell hydrogen to both Denmark and other countries.

The projects which primarily expect to sell hydrogen to Denmark are primarily small-scale projects measured in relation to electrolysis capacity.

In the interviews, several of the market participants have pointed out that the demand side in, for example, Germany is more mature than the current Danish demand. Market participants with large projects in the Region of Southern Denmark and the Capital Region of Denmark (including Bornholm) mention that connection abroad will be central to support the development of the largest production projects. The timing of when the infrastructure may be connected for consumption in Denmark and abroad, is therefore a decisive factor for the development of the hydrogen projects.

Figure 7. Expectation of sales from the hydrogen producing projects



*Note that the figure only contains figures for the hydrogen producing projects, i.e. projects that only produce hydrogen and do not use it. The figure does not include production figures for the integrated projects.

Hydrogen-producing projects expect to transport hydrogen in a pipeline infrastructure

The pure hydrogen-producing projects expect their production to increase heavily between 2025 and 2030.

The 22 projects that will solely produce hydrogen expect a large increase in their hydrogen production towards 2030 in Denmark. The production is expected to increase steadily throughout the period. The considerable increase in production from 2027 to 2028 is due to the owners of a number of the largest production projects expecting to commission the projects in 2028 and to a number of the projects increasing their production in the first years of commissioning.

The market participants expect the main part of the production volumes to be transported through a pipeline infrastructure.

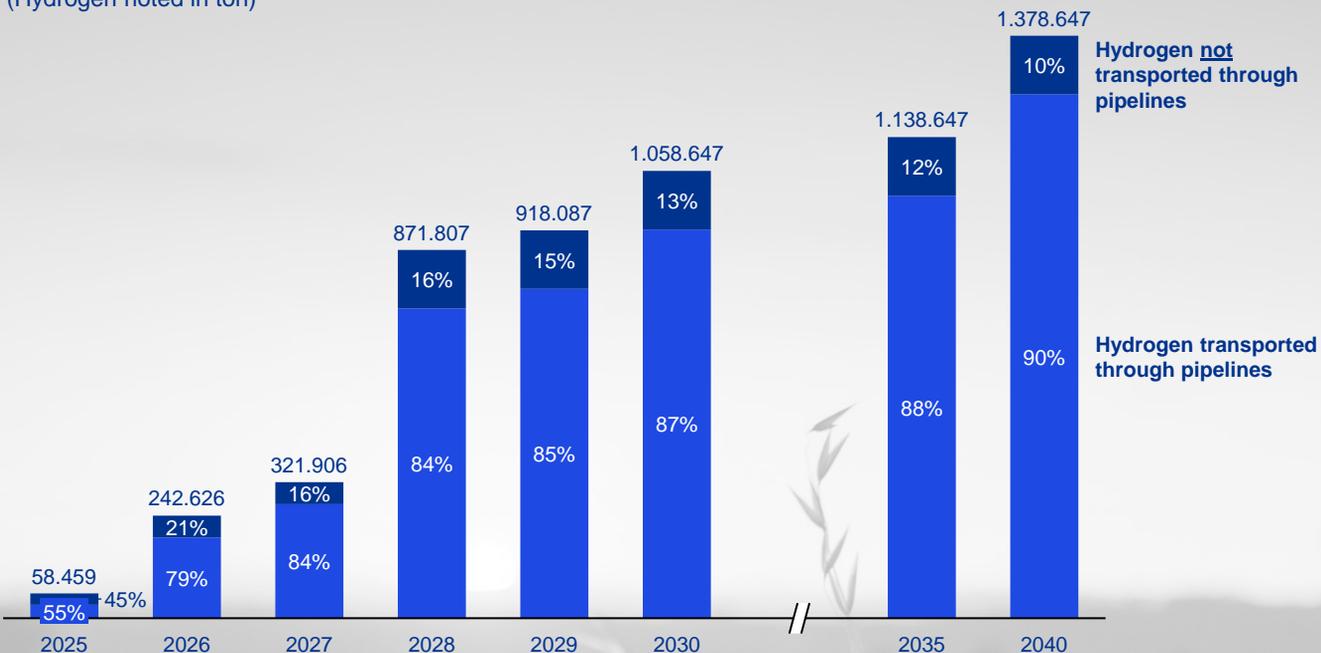
The market participants expect that a pipeline hydrogen infrastructure will transport the main part of the volumes produced, and this share is expected to increase during the period. From 2030 and onwards,

more than 87 per cent of the hydrogen production from the pure hydrogen projects is expected to use pipeline infrastructure.

The market participants have also been asked how long they expect to use the pipeline hydrogen infrastructure after the time of connection. Here, just under 90 per cent of the market participants respond that it will be 20 years or longer. In the interviews, the producers also stress the point that they envisage a long hydrogen infrastructure connection period due to the great operational and commercial advantages of being connected to the infrastructure. In the interviews, several market participants also point out that the possibility of using, for example, trucks for transport of hydrogen does not make sense to them for both logistical and cost-related reasons – typically due to the volumes to be transported.

Figure 8. Expected amount of hydrogen transported through pipelines, based on hydrogen producing projects

(Hydrogen noted in ton)



Barriers and requested initiatives

The market participants highlight a lack of knowledge about the future hydrogen infrastructure and uncertainty about costs and regulation as the main barriers for the development of the Danish hydrogen market.

In the questionnaire and in interviews, the market participants in all project categories were asked about the barriers they experience in establishing and operating hydrogen plants for production and use. More than 85 per cent of the respondent projects across different types and project sizes state that a lack of knowledge about which hydrogen infrastructure they can rely on is a significant challenge. Several respondents state in the interviews that, together with access to renewable energy, infrastructure certainty may be crucial in determining whether the project will be located in Denmark, as it will, for example, be difficult for the production projects to sell hydrogen in the expected volumes without a pipeline infrastructure.

In addition, the users of hydrogen emphasise, that on level with the lack of access to and knowledge about an infrastructure, uncertainty about the cost level and price level for hydrogen is a barrier to the success of their projects.

The market participants highlight five short-term initiatives which can be taken in relation to the establishment of a hydrogen infrastructure in Denmark.

The market participants highlight five initiatives which are of central importance to the ongoing work with the design of the hydrogen infrastructure and to supporting the realisation of the Danish hydrogen projects. The five requested initiatives are described below:

1. *Establishing a map of Denmark for the expected hydrogen infrastructure as soon as possible*

The most requested initiative among the market participants is to clarify where the hydrogen infrastructure is expected to be located as it affects both operational and commercial elements of the projects. Many projects state that they expect to make an investment decision in 2023/2024, making time a key factor in preparing the first hydrogen infrastructure map of Denmark.

2. *Clarification of cost model for transport of hydrogen*

Several market participants are calling for clarification regarding the future cost model for hydrogen transport. The primary concern from the market is the development of a model in which the first users of the hydrogen infrastructure will have to pay too high a tariff to cover the costs of the entire system.

3. *Establishing a clear hydrogen infrastructure governance model*

In the interviews, the market participants call for a clearer governance model and distribution of roles and responsibilities between Energinet, Evida, the Danish Energy Agency, the Danish Ministry of Climate, Energy and Utilities, municipalities and the private market participants.

4. *Large-scale hydrogen is a new field of expertise in Denmark – this aspect must be considered widely, including in the authority processes*

Several of the market participants have pointed out that it is vital to develop standards and specifications for aspects concerning emergency preparedness, security and possibly regulatory supervision, so that both private and public market participants have a joint basis for their work with the many hydrogen projects.

5. *Storage in connection with hydrogen infrastructure is of significant importance, and the storage facility in Lille Torup should be considered*

Several market participants point out that storage is a key value-creating element regarding the establishment of a hydrogen infrastructure. Several market participants see Gas Storage Denmark's storage facility in Lille Torup as an important infrastructure element.



The market dialogue was conducted through a questionnaire survey with the market participants in the PtX field and through interviews with the market participants.

The market dialogue was conducted by Energinet and Evida in cooperation with KPMG.

The market dialogue was conducted between August and October 2022.

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