INFORMATION PACKAGE 1
JUNE 2024

Danish Hydrogen Backbone

ENERGINET

Content

1. Introduction

In order to accommodate the market's need for information regarding the development of the Danish Hydrogen Backbone (DHB) and the framework for the future utilization of a Danish Hydrogen Transmission Network, Energinet will publish information packages to the market on relevant subjects. This is the first of two planned information packages in 2024. Information package 2 will be released in September 2024. Energinet expects to release further Information packages during 2025, to support the market in the user commitment process.

The information provided in this package is meant to provide the market with a direction for the development of the DHB and the framework for utilizing it. The information is based on Energinet's best available knowledge on the subjects at this point in time. However, a lot of work is yet to be finalized and a lot of the legal framework regarding hydrogen is not yet in place. For example, network codes entailing detailed regulation on certain subjects will be developed in the coming years. Therefore, the information provided is not final and may be subject to changes in coming information packages.

This information package contains:

- Status on user commitment process.
- A general overview of the expected physical project and possible connection points.
- General market conditions, focusing on the expected market model and market roles.
- A summary of the balancing model concept paper, released in April. An updated version is included in this information package.
- A description of the overall framework for hydrogen tariffs.
- A description of the expected framework for hydrogen quality.
- A description of the expected framework for network connections.

Energinet was appointed Hydrogen Network Operator together with Evida in the political agreement on hydrogen infrastructure[1] in May 2022. Energinet's role in developing and operating hydrogen infrastructure is to connect cross-border pipeline hydrogen infrastructure to a Danish receiving point, offshore pipeline hydrogen infrastructure and cross-border hydrogen pipelines across the country to a hydrogen storage facility, a so-called backbone. Furthermore, Energinet has the system responsibility for the future Danish Hydrogen Transmission Network.

[1] 1. Delaftale om mulighed for etablering af brintinfrastruktur

2. Status on user commitment process

Energinet needs user commitments in order to develop a business case in support of a conditional investment decision in Q1 2025, and in order to deliver market-driven build-out of hydrogen infrastructure in accordance with the political agreements on hydrogen infrastructure[2]. Several elements still need to be matured before Energinet can execute a sale of capacity contracts (such as a binding agreement with Gasunie Deutschland), and for this reason, Energinet's user commitment process contains two steps.

At the end of January, Energinet published a discussion paper about these two steps. Based on market feedback as well as dialogue with the Ministry of Climate, Energy, and Utilities and the Danish Energy Agency, the first step of the user commitment process became a market survey without legal or financial commitments, but with an emphasis on the market's ability to document the maturity of concrete hydrogen projects.

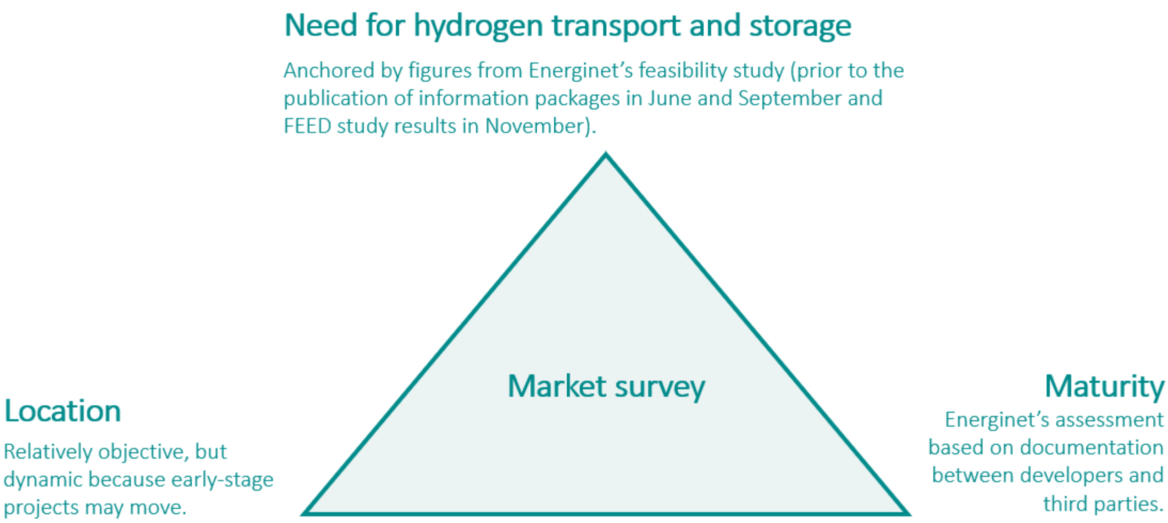

Figure 1: Key elements in the market survey (step 1).

Energinet received 30 responses from 15 market players and has shared the results with the Ministry of Climate, Energy, and Utilities and the Danish Energy Agency, which will be used in the coming political process as described in the second political agreement on hydrogen infrastructure[3]. The results of the market survey cannot be translated directly into capacity contracts/bookings because the market survey had no legal or financial commitments, and because it was based on cost estimates from Energinet's feasibility study, which amongst others will be updated by the Front-End Engineering Design (FEED) study that concludes in November 2024. The results of the market survey do, however, provide an updated view of the location, scale, and maturity of demand for a Danish Hydrogen Transmission Network .

[2] 1. delaftale: Mulighed for etablering af brintinfrastruktur & 2. delaftale: Økonomiske rammevilkår for brintinfrastruktur

3. Overview of the physical project

The proposed routings of the Danish Hydrogen Backbone (DHB) are presented in Figure 2. Two overall alternatives are currently being investigated, western Jutland and mid-western Jutland, as part of the route selection study in the ongoing Front-End Engineering Design (FEED) study. The routings are thereby subject to changes but overall, the depicted routes are deemed to be representative for the project. Selection of the optimal routing is part of the ongoing FEED study.

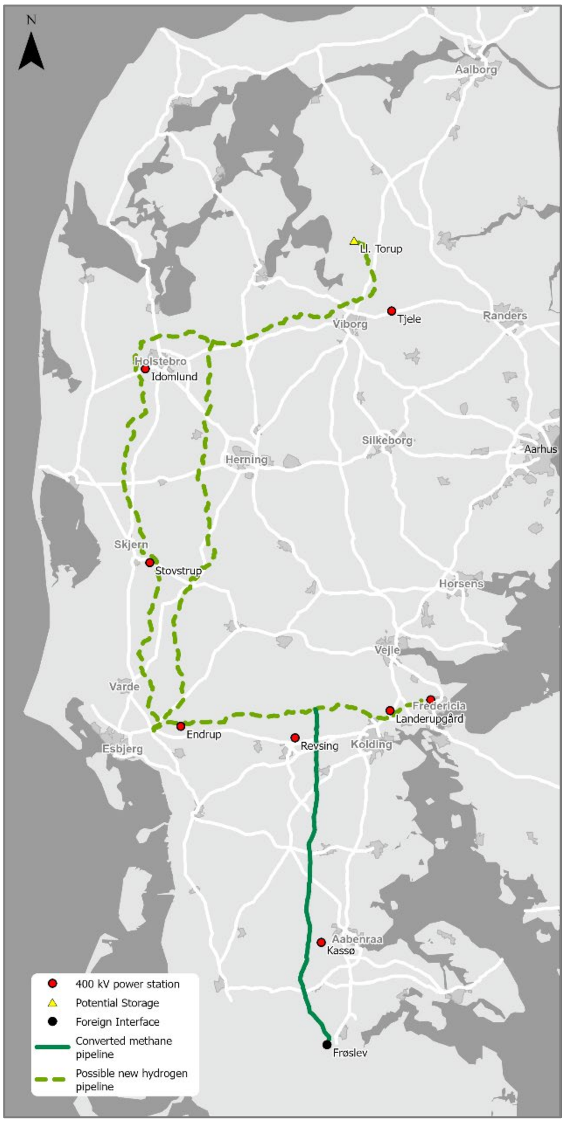

Figure 2: Proposed pipeline routes for the Danish Hydrogen Backbone.

The DHB, in its full form, consist of two different sections: a repurposed pipeline section and a section with new pipelines, with a total length of about 360 km. Given the immaturity of the hydrogen sector in Denmark and the significant cost establishing up to 360 km of pipeline, it is conceivable that this will be constructed in phases.

3.1 Repurposed pipeline

The methane pipeline "Frøslev-Egtved II" (FEII) from Egtved in Southern Jutland to Frøslev at the German border is planned to be repurposed (the exact crossing point for hydrogen still to be determined). If repurposing is feasible, it would represent an opportunity to reduce cost and reduce the time for the overall construction period of the hydrogen infrastructure. Conversion from methane use to hydrogen use requires testing and certification. At present the most likely outcome is that FEII will operate at a reduced pressure for hydrogen compared to methane.

For hydrogen the maximum operation pressure for the repurposed pipeline is expected to be 45 barg, with a design pressure of 49 barg. The minimum operation pressure is expected to be 35 barg. The diameter of the repurposed pipeline is 30" (outer diameter).

3.2 New pipelines

The upper part of DHB would be new pipelines, which stretches from West of Fredericia to East of Esbjerg, continues North in Western Jutland to West of Holstebro and finally connects to the gas storage facility in Lille Torup. The pipeline may end up with either of the two proposed routes. This pipeline will be new build and is expected to be a 36" diameter, although 42" has been considered. The exact size will be determined through the maturation phase. The full length of new pipeline would be between 270-280 km. The maximum allowable operation pressure is expected to be 90 barg and the minimum operation pressure is expected to be 50 barg. Energinet may reserve parts of the pressure band for system reserve. The exact system reserve requirements have not been defined yet. As with the repurposed pipeline the minimum pressure of this pipeline is not set by material factors but is due to the operation of the underground storage facility.

3.3 Capacity

The main purpose of the DHB is to provide significant capacity towards Germany. The exact capacity is depending on pipeline dimension as well as the configuration of the German hydrogen system, which has not been finalised yet.

- The repurposed pipeline, with its reduced size and limited pressure window imposes capacity limits, meaning that the throughput and maximum entry capacity is limited to approx. 3 GW_{H2} (LHV[4]).
- For a 36" new pipeline the maximum capacity is 7-8 GW_{H2} (LHV) given the pressure limit that are imposed on the pipeline.
- For a 42" new pipeline the maximum capacity is 10-12 GW_{H2} (LHV) given the pressure limit that are imposed on the pipeline.

The total capacity in the start grid is given by the capacity in the repurposed pipeline, corresponding to 3 GW.

If a low level of capacity initially is needed, Energinet may temporarily use the excess capacity to increase either linepack flexibility or lower operational cost by reducing maximum pressure.

3.4 Flexibility and fluctuating pressure

A pipeline is essentially a pressure vessel with multiple connections, and by applying a higher pressure at entry than at exit the hydrogen-energy will be transported. As an example, delivering 4 GW_{H2} (LHV) 300 km downstream of its injection point requires a pressure difference of roughly 7 barg. Any remaining pressure headroom to the maximum pressure, can be used as a short-term storage of hydrogen named linepack flexibility. The absolute quantity varies with the final dimensions of the pipeline and the available capacity.

The use of linepack flexibility and pressure to deliver hydrogen implies that the pressure will vary in the pipeline system dependent on how much hydrogen is stored. Hydrogen is generally expected to be produced from intermittent renewable energy sources and it is expected that part of this is balanced using linepack flexibility. Hydrogen production will have to be injected at the same actual pressure as in the network. For the network this means being able to adjust feed in pressure between 50 and 90 barg or expected 35 and 45 barg at the repurposed pipeline segments. As hydrogen production is not expected to operate at transmission pipeline pressures, there will be a need to increase the pressure at the connection point with a feed-in compressor.

[4] Lower Heating Value

3.5 Connection points

The location of hydrogen network connection points, for handling initial production and demand is based on current knowledge about potential hydrogen-projects and expectations about the landing of offshore wind power on the west coast. Two overall routings for the infrastructure and therefore different connection points are currently being investigated as part of the route selection study in the ongoing Front-End Engineering Design (FEED) study.

Valve stations positioned every 15-30 km along the pipeline allows for potential future expansion of the system, either by an extension of the hydrogen network, or by construction of additional connection points for production or offtake.

Figure 3 presents an overview of the hydrogen network and potential locations for the connection points. Selecting the location of the connection points is part of the ongoing FEED study; hence the connections points are subject to changes but overall, the depicted connections points are deemed to be representative.

Further elaboration on the framework for connections to the infrastructure is described in chapter 8.

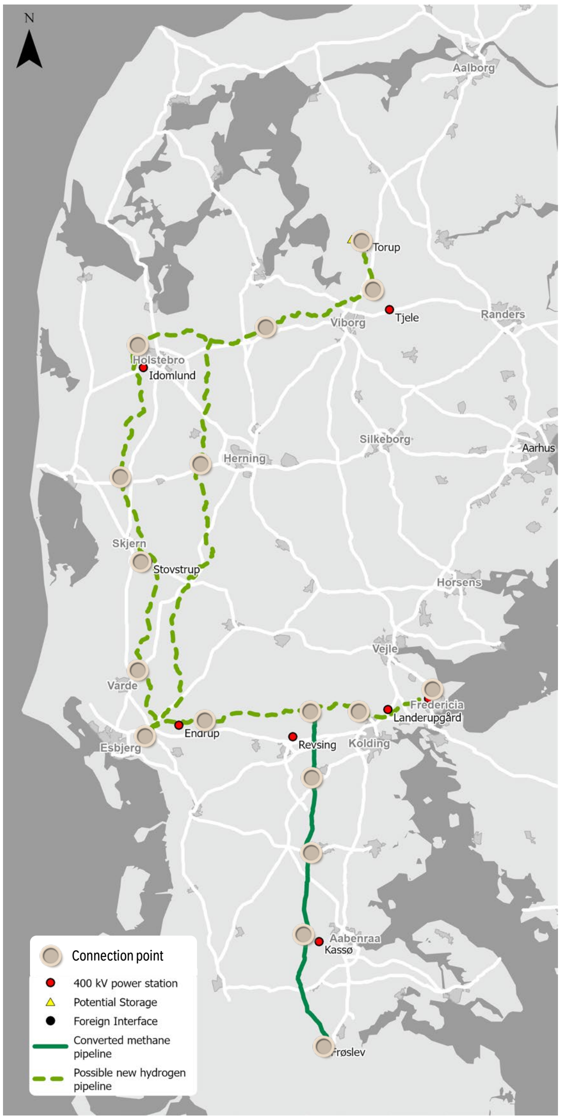

Figure 3 Proposed connection points for the Danish Hydrogen Backbone.

4. General market conditions

This chapter will give a brief introduction to two central elements in the market model for the Danish Hydrogen Transmission Network: the market access model (entry-exit model) and roles in the market model (third-party access to the services supplied by Energinet).

4.1 Entry-exit model

In terms of market access model, Energinet expects to organize a future a Danish Hydrogen Transmission Network as a so-called entry-exit market model from the commercial operation date (COD). This is also in line with the EU hydrogen and decarbonised gas market package stating that hydrogen networks shall be organized as entry-exit systems (from 1 January 2033).

What is an entry-exit model?

An entry-exit model is a market access model which allows network users to book capacity in any entry- and exit-point in the market area independent of each other. Hydrogen can thus be injected at the entry points and made available for off take at the exit points. It is a commercial mode designed and based on the physical conditions of the network in the market area.

Typically, a so-called virtual trading point in the entry-exit model is used as a point in which the network users can trade hydrogen bilaterally. It is not connected to a physical point in the network. The virtual trading point is designed to make sure that hydrogen can be exchanged independently of its location in the entry-exit model. In the EU hydrogen and decarbonised gas market package it is a condition that undertakings active in the same entry-exit system shall exchange hydrogen at the virtual trading point (from 2033 at the latest)[5].

Design of the entry-exit model

The expected entry-exit model is illustrated in Figure 4 below. Please note that the proposed points in the entry-exit model is expected to need approval by the Danish Utility Regulator.

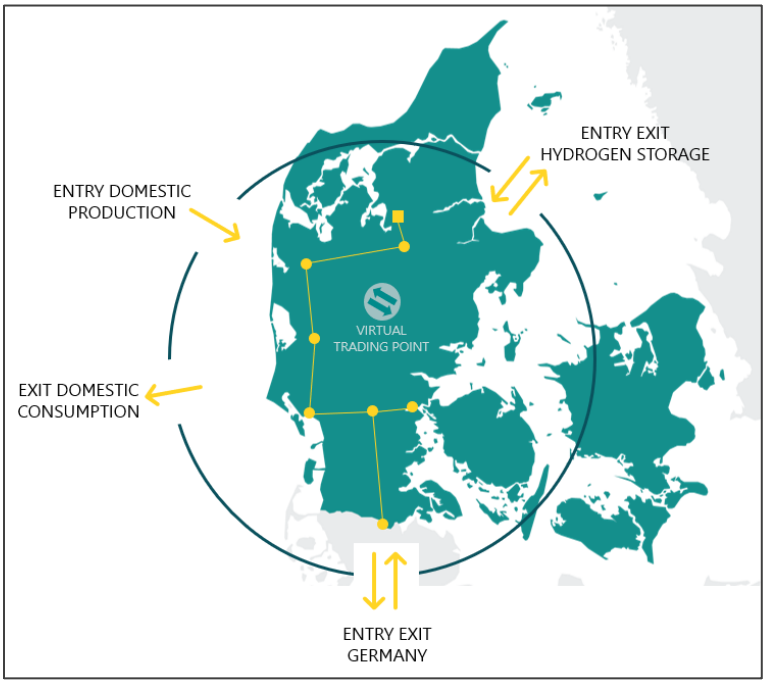

Figure 4: Illustration of the entry-exit model for hydrogen (COD).

[5] See Article 3 (d) in the EU hydrogen and decarbonised gas market package

The entry-exit model consists of the following points:

- **Interconnection point DK-DE – Exit**: Export of hydrogen from Denmark to Germany via Ellund.
- **Interconnection point DK-DE – Entry**: Commercial import of hydrogen from Germany to Denmark via Ellund[6].
- **Domestic production – Entry**: Supply of hydrogen to the market area from Danish production sites. This point is anticipated not to be strictly limited to one physical location in Denmark, as hydrogen producers should be able to supply hydrogen to the market area irrespective of their connection to the distribution or transmission network in Denmark.
- **Domestic consumption – Exit**: Withdrawal of hydrogen for consumption. As with the point above this point is anticipated not to be strictly limited to one physical location in Denmark.
- **Hydrogen storage – Entry and Exit**: In the Storage Exit point from transmission to storage, injection of hydrogen from the network to storage is made possible; in the Storage Entry point, from storage to transmission, withdrawal from storage to the network is made possible[7].
- **Virtual trading point:** A virtual trading point for the bilateral exchange of hydrogen. This point includes both trades executed on a possible future hydrogen exchange and for bilateral Over-The-Counter trades.

4.2 Roles in the market model

Background

It is a fundamental regulatory principle that Hydrogen Network Operators shall offer their services on a non-discriminatory basis to all network users. In the newly adopted EU hydrogen and decarbonised gas market package it is clearly stated regarding third-party access that hydrogen network operators shall offer their services on a non-discriminatory basis to all network users, subject to equivalent contractual terms and conditions for the same service.[8]

Hence, for Energinet it is important to outline how market players can get access to the different parts of a Danish Hydrogen Transmission Network, for example transportation of hydrogen or use of the hydrogen storage facilities. Furthermore, a description of the market players is a prerequisite for a clear understanding of legal responsibilities, invoicing rules etc.

In the same way the rules governing the use of the gas transmission system is described today, Energinet will establish a 'General Terms and Conditions for Hydrogen Transport' for the use of a Danish Hydrogen Transmission Network. This document will consist of a set of rules which together with the Framework Agreements[9] and other relevant appendices govern the market player's cooperation with Energinet regarding transport of hydrogen through the Danish Hydrogen Transmission Network.

To establish the rules for cooperation between the market players and Energinet, first it is vital to outline which roles define the market players. The description of the market players is important as it clarifies how the market player can act and get access to different parts of the transmission network, thus increasing transparency and securing a level playing field.

[6] It is expected that Denmark will predominantly export hydrogen to Germany. However, there can evolve commercial or balancing reasons over time, where market players would have an interest in importing hydrogen to Denmark, either virtually (as a counter flow to the dominant flow direction), or physically (if possible, and if counter flow exceeds the exit flow). Thus, having an entry point from Germany increases the possibilities for the market participants.

[7] Here shown as a part of the entry-exit model – but capacity can of course not be booked before the transmission infrastructure is physically connected to the storage facility etc.

[8] See e.g. Article 7 in the EU hydrogen and decarbonised gas market package, 'Third-party access services concerning hydrogen network operators' and preamble 87 relating to non-discriminatory third-party access to hydrogen storage facilities.

[9] Agreement between Energinet and the market player regulating the framework conditions which must be fulfilled in order to act in a Danish Hydrogen Transmission Network.

The purpose of this section is to outline a possible description and distinction between the different market players which can function as the basis for future work on the detailed rules for cooperation between the market players and Energinet.

Roles for the market players

From the first political agreement on hydrogen infrastructure from May 2023[10], the Danish hydrogen transmission network is expected to consist of a transmission network developed and operated by Energinet and a distribution network developed and operated by Evida. Some of the roles of the market players are relevant for the use of the infrastructure owned and operated by Energinet and some are relevant for the use of the infrastructure owned and operated by Evida. This section only describes the roles related to the infrastructure owned and operated by Energinet.

The terminology used below is in line with the terminology used in the EU hydrogen and decarbonised gas market package. The EU hydrogen and decarbonised gas market package defines two user-roles related to the hydrogen network: System Users and Network Users.

- System Users are in the EU-legislation defined as a natural or legal person supplying to, or being supplied by, the system.
- Network Users are in the EU-legislation defined as a customer or a potential customer of a system operator, and system operators themselves in so far as it is necessary for them to carry out their functions in relation to transport and balancing of hydrogen.

For the services in the Danish Hydrogen Transmission Network, following roles in the market setup is foreseen:

Market player role	Market player category description
Network User	Market player transporting hydrogen in the Danish Hydrogen Backbone. Responsible for balancing their deliveries and offtakes.
System User - Direct Hydrogen Consumer	Hydrogen consumers directly connected to the Danish Hydrogen Backbone.
System User - Direct Hydrogen Producer	Hydrogen producers directly connected to the Danish Hydrogen Backbone.
Hydrogen Storage Customer	Market players needing access to the hydrogen storage facilities (injection and withdrawal).

Table 1: Roles foreseen in the Danish Hydrogen Transmission Network.

The market player roles are visually showed in Figure 5 below.

10 1. delaftale: Mulighed for etablering af brintinfrastruktur

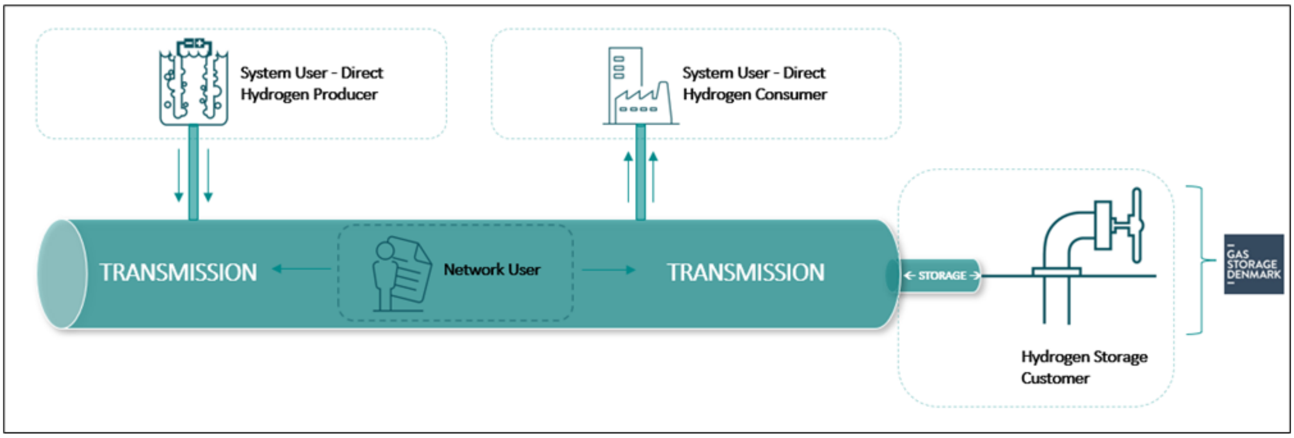

Figure 5: Market player roles in the Danish Hydrogen Transmission Network.

It is important to note that a natural or legal person can act in multiple roles at the same time. A natural or legal person producing hydrogen in Denmark who are directly connected to the hydrogen transmission network and engaged in transporting hydrogen via the network, will be acting as both 'System User – Direct Hydrogen Producer' and 'Network User' at the same time.

It is also important to note that the Network User role described here is also expected in the German Hydrogen Network (Core Grid).

Energinet will adjust the roles as the market develops over time.

5. Balancing model concept

With the implementation of a future hydrogen transmission network in Denmark, it is vital to outline and describe how to effectively balance the network. Physical limitations and legal framework conditions set the boundaries and/or opportunities for the design of the hydrogen balancing model. The objective of the hydrogen balancing model is to allow for large quantities of hydrogen transportation, while accommodating the demand from the Network Users for a flexible utilization of the Danish Hydrogen Transmission Network.

The EU hydrogen and decarbonised gas market package govern Energinet to foster the development of fair, non-discriminating, and transparent balancing rules. Furthermore, the articles demonstrate that the Network Users of the Danish Hydrogen Transmission Network are responsible for balancing their portfolios (deliverables and offtakes), to minimize the need for the Hydrogen Network Operator to undertake balancing actions. In addition to the legal framework, the physical limitations in a Danish Hydrogen Transmission Network have shown to be more stringent than for a natural gas system and more dynamic/loose than for the electricity system. The proposed balancing model is designed in such a way that each Network User is allocated their own Designated Linepack Flexibility (DLF)[11] conditioned on their booked capacity, while they can also utilize the residual of the System Linepack Flexibility (SLF), which is available to all Network Users.

The Network User is equipped with multiple balancing mechanisms, yielding a foundation for proactive balancing of their own portfolio (to avoid becoming Causers). Network Users causing the Accumulated System Balance (the accumulated balance of all Network Users) to cross its threshold will induce Energinet to activate TSO balancing actions to maintain the system balance. The costs of activating the TSO balancing actions will be allocated to the Causers. The TSO balancing actions consists of commercial and non-commercial balancing actions respectively. If commercial balancing actions are not available, non-commercial balancing actions in the form of prioritized cut-off is activated.

The prerequisite for flexible operation of the Network User's portfolio is knowledge on concrete price signals. Hence, an optimal coupling between the electricity market and the hydrogen market constitute to the foundation for utilizing the hydrogen transmission network.

Please note the balancing model must be approved by the Danish Utility Regulator before it can enter into force.

The full paper on balancing the Danish Hydrogen Transmission network can be found here.

[11] The DLF concept is subject to further regulatory analysis.

6. Framework for hydrogen tariffs

6.1 Outlines from the second political agreement on hydrogen infrastructure[12]

On 4 April 2024, the Danish government entered a second political agreement with a broad spectrum of parties in parliament concerning the economic framework conditions for a potential future hydrogen infrastructure and on the risk sharing between the State, Energinet and future infrastructure users.

The agreement establishes the fundamental principles of the future economic regulation and tariff methodology design while providing the necessary mandate to the Danish Utility Regulator and to the Danish Energy Agency to develop a detail regulation based on these principles.

The overall principles for the tariffs will be formulated by the Danish Energy Agency in an Executive Order, that will be issued before the market is asked to give a binding commitment. However, the framework conditions will require adjustment to the primary legislation (Lov om Gasforsyning) expected to enter into force 1 January 2025 based on which the detail regulation can be defined in secondary legislation and through future tariff methodology approvals. In general, the tariff methodology in Denmark must also be developed in accordance with the EU hydrogen and decarbonised gas market package and future network codes for hydrogen.

The Danish Utility Regulator drafts secondary legislation on economic regulation for the Danish hydrogen transmission network. As a regulated monopoly this regulation will set the yearly limits to the tariff revenue Energinet is allowed to collect. This makes the economic regulation the main legislative framework to regulating the tariff levels in the market's upstart period. To this end, the Danish Utility Regulator is expected to develop an inter-temporal cost allocation model as a part of the economic regulation, to transfer some of the initial tariff revenue to a later point in time. The Danish Utility Regulator is expected to present the general principles for revenue regulation and inter-temporal cost allocation before the market is asked to give a binding commitment. However, the Executive Order on regulation and inter-temporal cost allocation is expected to be issued in 2027.

Finally, Energinet is charged with drafting the tariff methods, that all must be approved by the Danish Utility Regulator before they can be implemented. Given that the economic regulation will determine the overall tariff revenue Energinet is allowed to collect, these tariff methods will only determine how the revenue is divided among the network users within a given year. The general principles for the tariff methods will be published before the market is asked to give a binding commitment. The finalized methods won't be issued until after the investment decision.

Energinet will strive to provide the market participants with regular updates during the period until the conditional investment decision in order to increase transparency and reduce the considerable economic uncertainty among those Network Users that will make long-term capacity reservation commitments. The Danish Utility Regulator as well as the Danish Energy Agency recognises the need to support the market dialogue during 2024 and 2025. The authority and agency aim to publish memos on the more detailed principles to supplement the second political agreement on hydrogen infrastructure ahead of the legislative process.

While the present information package 1 only contains the most general principles as defined in the second political agreement on hydrogen infrastructure, Energinet aims to improve basis for the decision-making among network users in the next information packages:

[12] 2. Delaftale: Økonomiske rammevilkår for brintinfrastruktur

1. Information package 2 is expected to include scenario-based indicative costs of transportation within certain assumptions including a spreadsheet model aiming to allow network users to calculate the impact of flow assumptions and perform sensitivity analyses on changes to the assumptions.
2. Energinets Front-End Engineering study will provide more robust investment cost estimates in November 2024. The parallel development on the regulatory framework should also serve to delimit the current uncertainties regarding the future economic regulation. Energinet aims to provide additional information in a package prior to user commitments in second half of 2025.

6.2 Economic regulation

The regulatory framework is required to consider an upstart hydrogen market with uncertainties. Hence, the political parties agree to provide a national regulation based on the EU hydrogen and decarbonised gas market package, which provides flexibility and reduces the economic risk carried by the first users of the hydrogen infrastructure with regards to give incentives to enter the market in its initial build-up stage. The start-up phase is not further defined but is expected to cover the period until the nascent hydrogen market has reached sufficient market penetration and has reached a critical volume to enable infrastructure users to carry the full network costs.

The hydrogen infrastructure constitutes natural monopolies that require an economic regulation aiming to protect its users against unnecessary costs. As is the case with the electricity and gas transmission and distribution infrastructure, a future hydrogen infrastructure will be revenue cap regulated based loosely on the present principles of the gas infrastructure regulatory model, adapted to facilitate an upstart market on the following principles:

- The Danish Utility Regulator is given the mandate to design the hydrogen revenue cap model. The development and implementation of the economic regulation will be conducted in a working group together with the Danish Energy Agency that will seek dialogue with market participants.
- Lacking a historical reference, the initial regulatory periods will be two years in order to allow faster adjustments to the regulation in its initial stages. The allowed revenue of first regulatory period will be based on cost applications made by the hydrogen network operators and subject to regulatory approval.
- During the initial phase of building and maturing the hydrogen market, the hydrogen network operators are exempt from regulatory efficiency targets to ensure the long-term economic sustainability of the hydrogen network operators, while there remain considerable uncertainties regarding the activities and transported volumes.

6.3 Inter-temporal cost allocation

The inter-temporal cost allocation mechanism is an integral part of the second political agreement on hydrogen infrastructure. The mechanism aims to postpone parts of the annual allowed revenues to a later point in time, where increasing hydrogen transport volumes are expected to materialize. This will alleviate potentially very high tariffs in the first years of establishing a hydrogen market with tariffs calculated closer to the long-term average cost of transportation.

This alludes to an option in the new EU hydrogen and decarbonised gas market package on implementing an inter-temporal cost allocation mechanism.

Rather than being a part of the tariff methodology, the inter-temporal cost allocation mechanism will be implemented by the Danish Utility Regulator as a part of the economic regulation. Energinet is in dialogue with the regulatory authority to allow the market participants to assess the impact on future tariffs.

6.4 Tariff principles

While the economic regulation will determine the allowed tariff revenue in any given year, the tariff methodology concerns how the allowed revenues are allocated to different hydrogen capacity products, network points and network users.

The basic principles of the hydrogen network tariff methodology are expected to be based on the capacity-driven entry-exit third party-access regime developed and applied to the methane (natural gas) transmission systems.

The model is based on sale of capacity independently into (entry) and from (exit) the Danish hydrogen transmission network to recover the allowed revenues of the hydrogen network operator. As is the case concerning the capacity allocation mechanism as well as the balancing regime, the detailed regulation is yet to be determined and will require regulatory approval before the rules comes into force.

Based on the second political agreement on hydrogen infrastructure, Energinet is inclined to implement a tariff methodology that holds the following characteristics:

1. Based on capacity bookings for entry- and exit points to the network.
2. Price differentiation between short- and long-term capacity.
3. Regulated 3rd party access from the beginning.

The basis product will be a one-year capacity with the possibility of buying shorter products at a mark-up price, like the current setup on methane (e.g. a one-month capacity will be prices as 1/12 the yearly capacity and increased with a predefined multiplier). The length of the different short-term products and the corresponding multipliers are still not decided, but Energinet intends to provide shorter within day products than what are available in the current methane methodology.

Following the second political agreements option for introducing incentives to the market for long-term capacity bookings, Energinet is also looking at the possibility of implementing a multiplier that makes it relatively cheaper to buy 10-15 years capacity, compared to a one-year capacity. However, given that there is no preliminary case for this in the methane system, Energinet will need to analyze the subject further. This analysis will amongst other things be centered around:

1. To what extend a lower multiplier for long-term bookings can be considered fair, reasonable, and cost-reflective, given that it will increase the cost of shorter products.
2. If an inter-temporal cost allocation methodology reduces the cost of the early user so much, that it is unreasonable to introduce further price incentives for the first movers amongst the market actors.

As mentioned above, all tariff methods need to be approved by the Danish Utility Regulator. Thus, Energinet cannot give any guarantee of how the final tariff method will be formulated, and the above thoughts on tariff method serves only as an insight to what Energinet expects to include in the method application to the Danish Utility Regulator.

7. Expected framework for hydrogen quality

This chapter presents Energinet's preliminary exit quality specification for hydrogen transported or distributed in a future hydrogen backbone. The specification is shown in Table 2. The hydrogen purity in a repurposed, or partially repurposed system is expected to be 99.5%.

To reduce the risk of potential trade barriers and cross-border interoperability issues, the content of the specification is, as much as possible, harmonized with ongoing standardization work in Europe, as well as in our neighbouring countries. However, the specification also attempts to consider expected future developments in the existing specifications, which may or may not be in force when the Danish Hydrogen Backbone becomes operational. Additionally, the specification attempts to take discussions at market dialogues and with market actors into consideration.

Energinet's specification was developed using the technical specification DS/CEN/TS 17977:2023 *Gas infrastructure - Quality of gas – Hydrogen in rededicated gas systems* as a base. Following the standardization mandate of the European Commission, which is awaiting final approval of the EU hydrogen and decarbonised gas market package, a process is expected to be initiated, which will utilize the CEN-specification as a starting point for developing a common European standard for hydrogen quality.

As CEN's technical specification is expected to be revised with suitable modifications before it becomes a European standard Energinet has chosen to deviate from CEN's technical specification for selected components. The components include the hydrogen, inerts, and hydrocarbon concentrations and possibly the water concentration. The hydrogen concentration has been increased from 98 mol% to 99.5 mol%, resulting in a decrease in the inert and hydrocarbon concentrations from 2 mol% to 0.5 mol%. These departures are aligned with our expectations for future modifications to CEN's technical specifications based on current activities and discussions in Europe. Energinet supports these changes. Additionally, the maximum water concentration is expected to be *either* 20 ppm (ASME B31.12 *Hydrogen Piping and pipelines)* or 60 ppm (maximum according to DS/CEN/TS 17977), depending on technical matters.

Table 2: Preliminary Energinet Hydrogen Quality Specification. Except where indicated by footnotes the specification is harmonized with DS/CEN/TS 17977:2023. The specification applies to hydrogen transport in a fully or partially repurposed infrastructure and indicates the guaranteed hydrogen quality at exit points.

Origin	Component	Abbreviation	unit	Value
H_2 Generation	Hydrogen	H_2	mol-%	≥ 99.5[b]
	∑ of inerts	(e.g. N_2, He, Ar)	mol-%	≤ 0.5[b]
	Carbon monoxide	CO	ppm[c]	≤ 20
	Carbon dioxide	CO_2	ppm	≤ 20
	Ammonia	NH_3	ppm	≤ 13
	Halogenated compounds	e.g. X-Cl/X-F	ppm	≤ 0,05
	Water	H_2O	ppm	≤ 20 or 60 [b,]
	Oxygen	O_2	ppm	≤ 1000 ≤ 10[d,e]
	∑ of hydrocarbons	C_xH_y	mol-%	≤ 0.5[b]

NG Infra-structure[a]	Hydrocarbon dew point	HCDP	°C	≤ - 2 at 1< p < 70 bara
	Total sulphur	-	ppm	≤ 7
	Particles	-	mg/kg	Technically free
	Odorization	Hydrogen shall not be odorized in the Danish Hydrogen Backbone and hydrogen shall be delivered unodorized at the Entry Points to the backbone.		
	Contaminants	The hydrogen gas shall not contain other components and/or contaminants than those listed in the table to an extent which can compromise the safety or integrity of the infrastructure, or which can prevent its transportation storage and/or utilization without further adjustment of the quality or treatment of the hydrogen gas.		
	Wobbe index	WI	MJ/m^3 (15/15) (25/0)	42,0-46,0[f] (44,3-48,5)

[a] These components most likely have their origin in the previous use of the pipeline. Occurrence is only expected in partially or fully repurposed systems.
[b] National departures from DS/CEN/TS 17977:2023.
[c] ppm on a molar basis is equivalent to mol/mol which is used on DS/CEN/TS 17977:2023.
[d] Max. 1000 ppm in grids with no exit point to UGS or to sensitive customers, otherwise max. 10 ppm.
[e] Expressed as a moving 24-hour average.
[f] In addition to the individual component limits the composition of the gas shall satisfy the Wobbe Index interval.

To ensure harmonization the development of Energinet's requirements is to a wide extend dependent on the ongoing standardization work across Europe (and in Germany). Energinet will continue to follow and contribute to the development of such international specifications and standards for hydrogen quality.

8. Expected framework for network connections

In Denmark, it is the Danish Energy Agency (DEA) who has the regulatory authority in relation to connections to the collective hydrogen infrastructure.

The DEA will in the fall of 2024 publish the Executive Order with the framework for network connection for consultation. In dialogue with the relevant stakeholders, the DEA have drafted rules for connection point (ownership/property limit) between the collective network and the connecting facilities together with the related cost allocation. For now, the related revision of the Gas Supply Act is in consultation.

In the drafted rules it is stated that the state-owned companies should own and operate all collective infrastructure with third party access. This means that it is the System Users responsibility to own and operate technical installation for a direct connection from System User facilities to the collective hydrogen infrastructure (with no third-party access) e.g. compressor units. The System User will carry all the cost for the direct connection facilities. The collective infrastructure can be expanded in cases of direct connections of System Users if it can be foreseen to be part of the collective systems with third party access and is economic efficient for the collective system. It is possible for System Users to influence the development of the collective system. For facilitating this process, Energinet are in ongoing dialogue with the market. Evida have also initiated a market dialogue to identify needs for local collective infrastructure.

The appointed connection point(s) for a System User will be decided individually by the two infrastructure companies Energinet and Evida, but mutually coordinated, according to objective, non-discriminatory and transparent criteria. The criteria should be approved by the Danish Utility Regulator. In the Executive Order there will be stated demands for process and argumentation and the decision of connection point(s) can be challenged by objection to the Danish Utility Regulator. Energinet are, as it is now, planning connection points for System Users at the valve station along the pipeline routing. Each direct connection will be assessed for the best operational and economic efficient location. In cases with two equal connection points from both infrastructure companies, the System User will choose the relevant connection point.

The challenges for System Users to construct pipelines and compressor connecting to the hydrogen infrastructure is currently being debated with the relevant parties to find a feasible way forward for the project developers. In the drafted rules it is made possible for Evida to establish a service company to offer such service to the market.

As mentioned in Chapter 3, Energinet is currently conducting a Front-End Engineering Design (FEED) study which includes a draft of routing and valve stations of the hydrogen infrastructure from a possible hydrogen storage at Lille Torup Gas Storage to the German border at Ellund. The location of valve stations will be drafted in the FEED study, and these will be the possible connection points to the system. Furthermore, Energinet is also working on operational scenarios and, as a consequence, the technical terms and condition for connecting facilities e.g. inlet pressure to the system.

9. Next steps

Going forward, Energinet will continue to involve market participants in the development of the Danish Hydrogen Backbone and the framework for the future utilization of a Danish hydrogen transmission network.

Energinet will release Information Package 2 during September. If deemed necessary and possible, Energinet will publish additional papers throughout 2024.

Following the release of Information Package 2, Energinet will invite all market participants to participate in a physical market meeting in September 2024, where elements from the Information Package will be explored. An invitation to the event including more specifics will follow soon. Also, Energinet will from August involve market participants in the development of the terms & conditions for the user commitment Step 2 process.

The process for involving market participants in 2024 is illustrated in figure 6 below.

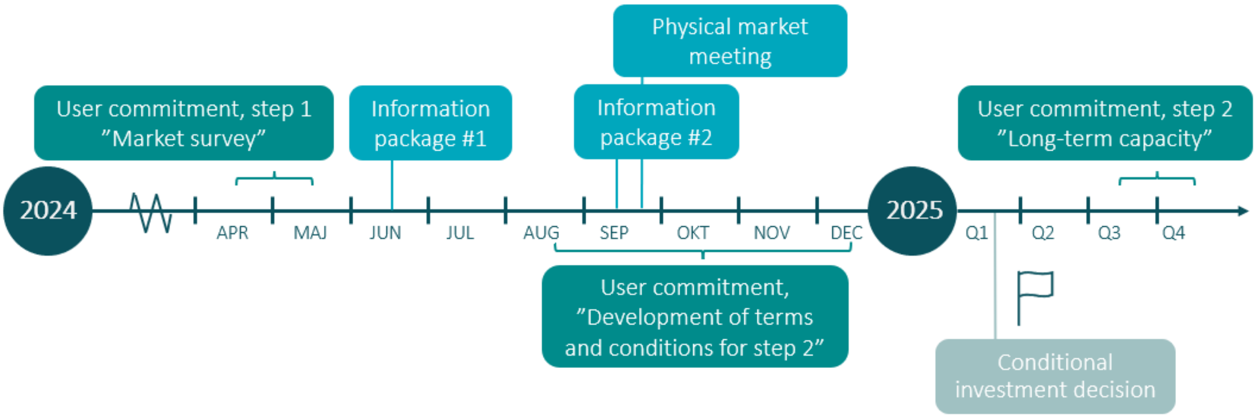

Figure 6: Process for market dialogue in 2024.

Information Package 2

The topics planned to be included in Information Package 2 is listed below.

1) Information on German project and process
2) Expected overall market framework
3) Tariff design concept
4) Transportation cost estimations
5) Expected framework for network connections version 2
6) Information on first filling of the pipeline

User commitments

It is Energinet's expectation that the user commitment Step 2 will be performed during second half of 2025. It is also Energinet's expectation that parts of the Step 2 terms and general market framework will be subject to approval by the Danish Utility Regulator (DUR).

To secure a sufficient and timely process towards DUR, Energinet is working towards having the terms & conditions for Step 2 and corresponding method applications ready by end-2024. Energinet will involve market participants in the development of the terms & conditions in two Steps during the coming months (here listed with expected timings):

- August 2024: Energinet will publish concept paper for the user commitment step 2.
- September 2024: Dialogue with market participants in concept paper, including joint dialogue meeting.

- October 2024: Energinet publishes draft terms & conditions for step 2 and corresponding draft method applications for market consultation.
- November 2024: Consultation period.
- December 2024: Energinet will finalize and forward terms & conditions for step 2, and method applications towards DUR for approval.

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