HyRegions 2

Low-pressure hydrogen networks essential for decarbonisation of regional industry and the integral energy system

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Contents

1. Summary

Hydrogen is set to play a crucial role in the future energy system. Construction of a national hydrogen network is already underway and regional hydrogen networks will also be needed to support the decarbonisation of regional industry. The HyRegions study conducted in 2024 identified 11 regional industrial clusters. In this HyRegions 2 study, network operators sought to answer the following main question: 'How can companies based in regional (concentration) areas be provided with hydrogen infrastructure at the lowest possible network cost?'

This follow-up study looked for archetypes that can be used to describe, classify and prioritise areas, aiming to deliver a blueprint to be able to determine in what order to develop areas. A blueprint was also believed to help adopt a generic approach to building regional hydrogen distribution infrastructure.

The study analysed three very different industrial concentration areas to see what steps are needed to build the optimal infrastructure in each of these areas. To assess what would be the optimal infrastructure, the study detailed three possible network designs:

- Hybrid: companies are connected based on their optimal or required supply pressure (high/low)
- Low pressure (LP): network design based on low-pressure networks
- High pressure (HP): network design based on high-pressure networks

Analysis of the following technical and financial aspects showed that a low-pressure network is the best supply option for most regional companies:

- Cost elements: the cost of a high-pressure network turns out to be 2.5 to 10 times higher than that of a low-pressure network.
- Technical drivers: most companies in the industrial concentration areas studied want a gas pressure of below 16 bar (75% of the total of 36 companies surveyed). In the cases studied, it turns out that adding a compressor to a low-pressure network to be able to also serve customers who want a higher gas pressure is a more cost-effective option than building an entire high-pressure network or a hybrid network.
- Area-specific factors: high-pressure infrastructure cannot be accommodated everywhere, mainly because it involves greater risk contours than low-pressure infrastructure. On the other hand, however, it is not always possible to serve a customer with specific demand for (very) high capacity using low-pressure infrastructure.

The study did not reveal any archetypes for the prioritisation of areas, meaning that it proved impossible to develop a blueprint that will accelerate area development. Each area will require a customised approach.

Cluster 6 has pointed out that regional companies currently feel that they have insufficient scope to take action in decarbonising their operations. The network operators are seeing that regional companies, but also provincial and local authorities, want to get started with hydrogen and are launching projects to do so. At the same time, however, the lack of clarity on how the hydrogen market will be regulated and what roles this will involve, means that it is impossible to say at this point whether it will be possible to connect such decentralised hydrogen networks to the national network in the long term.

The network operators recommend the following next steps:

1. Develop the first regional case studies
2. Draw up a development plan for regional hydrogen
3. Clarity on market regulation.

2. Introduction

2.1 Background and objective: lack of scope for action for regional parties

Hydrogen is set to play a crucial role in the future energy system. Gasunie subsidiary Hynetwork Services B.V. has meanwhile started building the national hydrogen network. Alongside this national network, regional hydrogen networks will be needed to help decarbonise regional industry. The HyRegions study from 2024 took stock of the need for regional hydrogen infrastructure and established organisational principles and conditions for the roll-out of such networks in Cluster 6. This study showed that hydrogen will also fulfil a role outside the five industrial clusters from 2030 onwards.

However, choosing between these areas was not in scope for the first HyRegions study, which is why the network operators conducted a follow-up study: HyRegions 2.

This study sought to answer the following main question: 'How do we provide companies based in regional (concentration) areas with hydrogen infrastructure at the lowest possible network cost?' It explored the differentiating features and design principles that determine how a regional network is developed, while assessing the following technical and financial aspects:

- **Cost elements**, total network cost, made up of capital expenditure (material, construction), operating expenditure, and other costs.
- **Technical drivers**, such as supply pressure for users, the available pressure in the network, the amount of hydrogen required, and striking a balance between pipeline diameter and pressure drop.
- **Area-specific factors**, such as geographic or energy-related features and risk factors that affect design choices.
- Societal aspects such as the ambitions of companies, local authorities and network operators were not included in the study.

This follow-up study looked for archetypes that can be used to describe, classify and prioritise areas, aiming to deliver a blueprint to be able to determine in what order to develop areas and define a generic approach to building regional hydrogen infrastructure. The chosen approach was to detail the steps needed to build the optimal infrastructure in three industrial concentration areas with very different characteristics, which were taken from the initial HyRegions study. This follow-up study looked at what investments are needed (based on indicators) and how, from a societal perspective, to best divide the duties and responsibilities between national and regional network operators and the connected parties. This study shows that there are no archetypes for the development and prioritisation of the areas and that each area requires a customised approach, which led to the decision not to study any additional areas such as stand-alone areas or those assigned priority status under the long-term infrastructure for energy and climate (*Meerjarenprogramma Infrastructuur Energie en Klimaat*, MIEK). However, working out the specifics of only three areas did end up delivering greater insight into how to approach network development.

It is important to stress that the results for specific areas in this study should not be considered a specific course of action for area development, but rather answers to the research questions. In practice, the development of hydrogen infrastructure in these areas will differ from what was studied, depending on how demand for hydrogen develops in these areas and how fast hydrogen production, supply or connect to the national network can be realised. However, this process will only get started once choices have been made as to where hydrogen will be used to decarbonise regional industry.

The network operators furthermore see a regional need arise for infrastructure at locations outside the industrial concentration areas, based on other drivers (industrial ambitions, production sites). With the HyRegions 2 study, the network operators present the outlines of a clear contribution to the development of regional hydrogen networks, with the aim of enabling decarbonisation of regional industry.

In addition, this study advises on future growth and what branches will be needed for regional hydrogen infrastructure. In this respect, it is helpful to, while building on HyRegions 1, paint a picture of how to organise network operation. These insights will help drive market development and give direction to choices on how to organise and regulate that market. Additionally, they provide a basis for the further drafting of policy, laws and regulations around the development, construction and operation of regional hydrogen networks. By embarking on a future-driven and joint thought process on what is needed to set up these networks in a future-proof manner, the network operators are helping to ensure a robust, integral and cost-efficient energy system.

2.2 Assumptions and basic principles

This study used the following assumptions with respect to the design of the regional networks:

- Hydrogen is transported in gaseous form through underground pipelines.
- The companies based in each area are assumed to have high willingness to pay[1] in switching to hydrogen to decarbonise their business processes.
- The assumption here is that such an area can be switched to hydrogen in one go, which is a ‘theoretical exercise’, i.e. all parties want to use hydrogen, they can all switch their processes to hydrogen at the same time, all the required infrastructure is built, etc.
- Since they are considered public infrastructure, regional hydrogen networks must be accessible to all connected parties on equal terms.
- Private, stand-alone areas are not in scope for this study.
- The indicators offer a realistic estimate based on a quick scan of customer demand and area analysis.

The basic principles underlying this study are as follows:

- References to regional areas in this study are references to Cluster 6 industry. Other sectors were not included in the scope (mobility, built environment).
- This study only looked at network investments up to the custody transfer point (supply station) at the receiving company. The aim is to keep network costs as low as possible and not to use taxpayer funds for specific customer needs, such as purification, redundancy, etc. As a result, statements on network costs only relate to the generic transport service provided to all customers on equal terms. The costs of company-specific adjustments to a company’s connection, except for the installation of compressors used to raise the pressure rating, will be borne by the company in question.[2] This estimation of the costs involved does not include an assessment of how desirable it is to be able to reduce the pressure from the high-pressure network to the low-pressure network to subsequently increase the pressure using individual compression and the impact on capacity expansion in the future.

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[1] Willingness to pay as used in the original HyRegions study (2024) correlates with the degree to which companies have suitable sustainable alternatives to meet their energy needs.

[2] Exceptions to this are the costs involved in fulfilling specific customers’ pressure requirements in alternatives 2 and 3, because this study assumes one single network (fully low pressure/high pressure), without taking into account these customer requirements.

- In the study, the design of a network in an industrial concentration area is based on the assumption that all hydrogen demand is known and specific, which creates optimal conditions for development of the entire network. This will likely not always be the case in reality, as it depends on company-specific choices and timing whether demand for hydrogen will actually materialise and a network can be developed. This study does not consider the future growth of the connected parties, or other companies that may be connected to the network.
- The network will be designed/built as a single network, because this is the optimal way to do it for regional networks, as it has also proven to be for the current gas distribution systems.
- This study does not take into account the possibility of repurposing existing natural gas infrastructure for hydrogen transport. Depending on local circumstances, gas pipelines from the various network sections can be reused. This study does not consider these possibilities.
- To determine which customers will be included in the development of a specific area, the study:
    - Uses the list of companies (cat. A + B willingness to pay) from HyRegions 1, plus
        - companies from category C (from HyRegions 1) that may want to use hydrogen (because hydrogen would be a good alternative for them due the specifics of their processes), plus
        - information on companies in the industrial concentration areas that have indicated to the network operator that they are considering getting connected to hydrogen infrastructure.
    - HyRegions 1 estimated the expected hydrogen consumption based on current natural gas consumption levels and the expected percentage-based decarbonisation by switching to hydrogen. To get a better picture, HyRegions 2 reached out to companies to make a realistic estimate of the expected consumption of hydrogen, including the capacity and required supply pressure of the gas.

      When companies chose not to share any information, the study used the expected hydrogen consumption figure from HyRegions 1 and took the current natural gas connection to the regional distribution system or national grid (pressure lower or higher than 16 bar) as the basis for the required supply pressure rating.
    - The study assumed that the national network operator will be developing networks with a pressure range of 30 to 50 bar (which can ultimately grow to 66 bar).
    - The regional network operators will develop networks with network pressure ratings of up to 16 bar.
    - It must be noted here that the supply pressure at the customer's end is not the same as the network pressure. Hynetwork is able to deliver hydrogen to a specific customer at low pressure over a high-pressure network.
- The current gas system has a 'natural' boundary of 16 bar to differentiate between the operating areas of high-pressure networks and low-pressure networks. Since each operating area is subject to specific laws, regulations, codes and standards, and comes under a different supervisory authority, there are different materials and components, work instructions, etc. For the sake of efficiency in performing the network operator role, the current differentiation has been used.

3. Method

3.1 Three network configuration scenarios

In looking for archetypes that can be used to describe, classify and prioritise areas, the specifics of the areas were worked out based on the three design options that determine the network configuration. It must be noted here that high-pressure and low-pressure networks each have their own characteristics and purpose, and that they are not always interchangeable. In developing the infrastructure, the aim will ultimately have to be to find the most favourable option in terms of distance, capacity, pressure, costs, feasibility and lead time, so as to be able to align with the pressure and capacity that the market needs, whereby the market is made up of all connected parties.

Alternative 1 Hybrid: companies are connected based on their optimal or required supply pressure (high/low) or flow rates[3]

- The required supply pressure determines whether customer connections fall into the high-pressure or low-pressure network domain.
- Customers who need hydrogen supplied at low pressure will be connected to low-pressure infrastructure, unless they need (very) high capacity. Customers who need hydrogen supplied at high pressure will be connected to high-pressure infrastructure.
- From these two networks, further optimisations will be implemented until there is one interconnected network with one or multiple connections to the national hydrogen network.

Alternative 2 Low pressure (LP): network design based on low-pressure networks

- All companies will be connected to the hydrogen supply using low-pressure networks and will be supplied with hydrogen at a network pressure rating of below 16 bar.
- Customers who want their hydrogen supplied at 16 bar or at a higher pressure rating will need a compressor. This has been factored into the cost estimate.

Alternative 3 High pressure (HP): network design based on high-pressure networks

- All companies are connected to the hydrogen supply using high-pressure networks.
- For customers who want a lower supply pressure rating, the pressure can be reduced at the hydrogen delivery station.

3.2 Area selection

Areas were selected from the list of industrial concentration areas from the first HyRegions study. A choice was made to focus the study on the north-eastern part of the province of Groningen, the Dongen/Tilburg area and the Betuwe area because of:

- The differences between these areas in terms of characteristics and complexity (number of connections, civil engineering structures, distances within the area, and geographic features) to ensure that the analysis provides insight into a wide range of considerations/factors;
- The availability of information to enable a quick analysis;
- The overlap of service areas, which means that multiple network operators are involved and that collaboration will be required, which is something that will increasingly be expected in the future.

[3] Flow rate: the amount of hydrogen supplied over a specific unit of time, which for gases is generally cubic metres per hour (m^3/h).

3.3 Network section analysis approach

In order to analyse the areas consistently, a choice was made to work out the specifics of each area in the same way.

To get a basis for the network design, all A/B/C customers, as defined in HyRegions 1, were surveyed, asking them how much hydrogen they expect to need and at what pressure they would need it to be supplied. The results of this survey provided insight into the spread and extent of hydrogen demand in each area, offering an essential starting point for the first network design drafts.

Having taken stock of customer needs, the network designers made a first draft of the network design, calculating the maximum flow rate and pressure drop in the system. Next, Antea Group added further substance to these drafts by conducting a quick analysis of network sections, which looked at the following subjects:

1. Technical assumptions
2. Alternative network sections and sub-sections
3. Environmental aspects
4. Legal and regulatory framework and stakeholders
5. Risk inventory and mitigating measures
6. Implementation and construction cost estimate and timetable

A summary of the results of these underlying analyses are available separately from the following persons:

- North-eastern Groningen and Dongen/Tilburg: Chantal Spierings at Enexis, who can be contacted at chantal.spierings@enexis.nl
- The Betuwe area: Axel Schnoeckel at Firan (Alliander), who can be contacted at axel.schnoeckel@firan.nl

3.4 Financial analysis

The network section analyses contain important information on the pipelines in the three scenarios. This information was enriched with financial details of supply stations and compressors where necessary for a more detailed financial analysis. Cost was estimated based on a period of 30 years, while keeping the cost structure simple so that cost can be subdivided into three categories that are further specified in the results for each area:

- Capital expenditure (CapEx): costs resulting from the initial investment in the pipelines and supply stations. Replacement costs were not included for assets with a service life that is shorter than the term of 30 years.
- Operating expenditure (OpEx): the annual operating costs incurred to operate the network. The study used a fixed percentage of capital expenditure for operating expenditure. This percentage was assumed to be 4% for stations and pipelines and 10% for compressors.

With a view to improving reliability, a sensitivity analysis was conducted based on the cost of the supply stations.

3.5 Feasibility

Based on the scenarios, the study also looked at the feasibility of the regional hydrogen network and the extent to which it can be accommodated in the various areas. Given that design principles and permit requirements are not the same for low-pressure and high-pressure networks, the study had to review whether there are any factors impeding either a low-pressure network or a high-pressure network in each area. Spatial planning challenges that come into this include the extent to which the area is built-up (urban versus agricultural area) and intersections with other infrastructure, water barriers such as dikes, and Natura 2000 nature protection areas.

4. Results

This study sought to answer the following main question: 'How can companies based in regional (concentration) areas be provided with hydrogen infrastructure at the lowest possible network cost?' It explored the differentiating features and design principles that determine how a regional network is developed, while assessing the following technical and financial aspects:

- **Cost elements:** total network cost, made up of capital expenditure (material, construction), operating expenditure and other costs.
- **Technical drivers:** such as required supply pressure for users, the available gas pressure in the network, the amount of hydrogen required, and striking a balance between pipeline diameter and pressure drop.
- **Area-specific factors:** such as geographic or energy-related features and risk factors that have a bearing on design choices.

Societal aspects such as the ambitions of companies, local authorities and network operators were not included in the study.

4.1 Cost elements

High-pressure and low-pressure networks are both made up of two main components: pipelines[4] and stations (pressure reduction steps). These components account for most of the total cost of a network of either type. With this in mind, HyRegions 2 compared the cost of pipelines and stations for high-pressure infrastructure to the cost of pipelines and stations for low-pressure infrastructure. The cost of a high-pressure network turned out to be 2.5 to 10 times higher than that of a low-pressure network.

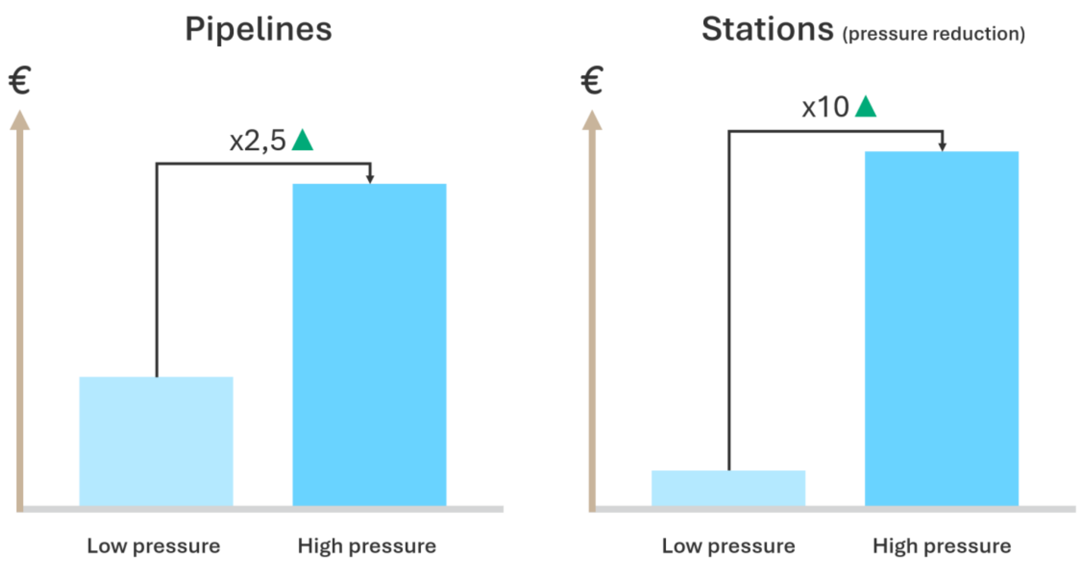

Figure 1: pipeline and station cost comparison for low pressure and high pressure

In addition, a network cost model was drawn up to capture the asset costs for the high-pressure and low-pressure networks. This model was used to work out the cost of three network versions where low-pressure customers are supplied hydrogen through a high-pressure network, a low-pressure network,

[4] Cost includes the cost of design and construction.

or a hybrid network. It confirms that supplying customers with hydrogen through a low-pressure network is financially more attractive than using a high-pressure network or the hybrid version.

The finding that smaller-capacity infrastructure and assets are less cost intensive than heavier infrastructure is, in itself, not new. It is something we have also seen in the existing energy infrastructure for electricity and natural gas, and in the layering of other kinds of infrastructure, such as water mains, roads and telecom infrastructure.

Details by area

Tables 1 to 3 break down the capital expenditure and operating expenditure for each area. These tables show that an LP network is always the lowest-cost option and that it differs per area whether the HP or hybrid scenario is more expensive in terms of operating expenditure.

Table 1: Cost breakdown for the north-eastern Groningen area

Groningen	LP network	HP network	Hybrid
CapEx (in millions of euros)	€65	€121	€128
OpEx (in millions of euros)	€7.0	€9.9	€10.4

Table 2: Cost breakdown for the Dongen/Tilburg area

Dongen/Tilburg	LP network	HP network	Hybrid
CapEx (in millions of euros)	€19	€33	€27
OpEx (in millions of euros)	€1.9	€2.7	€2.6

Table 3: Cost breakdown for the Betuwe area

Betuwe	LP network	HP network	Hybrid
CapEx (in millions of euros)	€81	€190	€140
OpEx (in millions of euros)	€7.1	€15.0	€9.8

4.2 Technical drivers

A key technical driver is which customers want a specific supply pressure. The customer survey shows that customers require a wide range of different supply pressure ratings and flow rates. Most companies in the industrial concentration areas studied want a pressure rating of below 16 bar (75% of the total of 36 companies surveyed). This means that a low-pressure network (under 16 bar) will not be able to provide every customer with the pressure they want. When choosing to only build a low-pressure network in an area, the pressure would have to be increased for this small group of customers using a compressor. The financial analysis shows that when including the resulting compression costs, a low-pressure network is still the cheaper option compared to a high-pressure network or a hybrid network.[5]

[5] While pure application of the cost causation principle would see each individual customer bear the costs of compression, this study does include these costs in the total cost to provide insight into the sensitivity of the various design options. This does not mean that the study argues in favour of or against socialising these costs.

4.3 Area-specific factors

High-pressure infrastructure cannot be accommodated everywhere, mainly because it involves greater risk contours than low-pressure infrastructure. Accommodating high-pressure infrastructure in an area is complicated especially by city centres, densely built-up areas, water barriers such as dikes, and other obstacles. The spatial impact of high-pressure infrastructure means that there will be more land owners involved, which means more coordination and the acquisition of privately owned land. This is easier with low-pressure networks, as these can often be laid under public land. Arrangements with local and permitting authorities will pave the way for faster construction of the network. Therefore, when it comes to accommodating the network in an area, there is a preference for the low-pressure option.

With the exception of a small number of customers who are located close to the national hydrogen network and/or who are high-volume users or need a high pressure rating, most customers surveyed would be best served by one (or several) system connection(s) and a low-pressure network. As and when the area is actually developed, further optimisations may be implemented for the phasing and specific customer needs, possibly combined with the location of the system connection. However, in this study, these factors do not mean there is reason to choose a fundamentally different design option.

This study shows that the construction of hydrogen infrastructure faces various spatial planning challenges, depending on the specific characteristics of each area. From urban bottlenecks to water barriers, nature reserves, agricultural land and archaeology, each network section comes with its own specific complexity. The following will detail the main spatial planning challenges and bottlenecks in each of the areas studied.

Findings - SPATIAL PLANNING CHALLENGES

Urban and agricultural challenges

In the **Dongen/Tilburg** area, existing cables and pipelines in urban areas constitute a key factor to consider in building a hydrogen network. The space available for a new hydrogen pipeline is limited by the numerous underground pipelines and cables that already run near industrial estates and alongside existing infrastructure. Trial trenches and detailed coordination with network operators will be needed to determine where the hydrogen pipeline can be laid safely. The presence of trees along the network section is another bottleneck. To prevent damage to these trees' roots, directional drilling will be needed at various locations.

In the **Betuwe** area, the subsoil begins at a depth of only 10 metres, which limits the scope for drilling. Another major obstacle in the Betuwe area is the presence of **vast orchards**. Open excavation is basically impossible there due to the major damage it would do to crops and tree root systems. As a result, many parts of the pipeline would have to be laid using drilling, which not only comes with additional costs, but also complicates the feasibility of certain parts of the network section. It has also turned out that the **high-pressure network section in the town of Gorinchem is difficult to build** due to the very limited space available and the presence of urban water barriers. The combination of the protected status of these water barriers and the built-up urban area makes it highly expensive/infeasible to lay the high-pressure pipeline in a way that is safe and in compliance with current regulations. This means that for one specific company it is impossible to provide a high-pressure connection.

In the **eastern part of the province of Groningen**, the challenge lies in the routing of the network through both an urban and an agricultural environment. In the centre of the town of Veendam, the pipeline would have to be laid under narrow streets that already have numerous cables and pipelines running underneath them, which leaves little space for a hydrogen pipeline. Aside from that, part of the network section would run alongside two roads (N366 and N367), where additional traffic arrangements would be needed and there is limited space available for the pipeline.

Intersections with infrastructure and water barriers

In the **Dongen/Tilburg** area, the pipeline would have to cross the Wilhelminakanaal canal. Since open excavation is not an option here, the only remaining option is directional drilling. This not only involves additional costs, but it also requires detailed coordination with Rijkswaterstaat.

The network in the **Betuwe** area is highly conditioned by its intersection with the river Waal. The pipeline under the river would have to be inserted through directional drilling along a long stretch of approximately 1,300 metres, which would be a technically challenging and costly operation. In addition, part of the section runs through a groundwater protection area, where excavation is subject to strict rules. Other parts of the section run through areas with protected water barriers. The pipeline is not allowed to just cross these barriers, and coordination with water boards would be needed to unlock alternative routes or technical solutions, such as drilling at greater depth.

In the **eastern part of the province of Groningen**, too, water barriers play a role, especially near the town of Winschoten, where the pipeline would run alongside a railway line. Coordination with rail infrastructure manager ProRail would be required to make sure the pipeline complies with safety standards.

Nature and archaeology: protected areas and historic sites

In the **Dongen/Tilburg** area, archaeological sites are an important focus point, especially near historic village centres. Where possible, the pipeline will circumvent these sites, but additional analyses and alternative pipeline laying methods will be needed in some places.

In the **Betuwe** area, the network section borders on several Natura 2000 nature protection areas, such as the Rijntakken reserve along the river Waal. This would require proof that network construction will not produce additional nitrogen depositions, otherwise the project could be denied a permit.

In the **eastern part of the province of Groningen**, too, archaeological values must be taken into account. The network sections intersect with historic flood refuge mounds and old watercourses, which necessitates additional archaeological investigation before construction of the network can start.

5. Conclusions

5.1 No archetypes for prioritisation

This study set out to define recognisable, differentiating characteristics in the three areas studied that can serve as archetypes applicable for multiple areas. The aim was to enable prioritisation of areas using these archetypes, and to subsequently use such a blueprint to accelerate the development of areas. However, the study did not identify any differentiating features that are universally applicable. As a result, the study has not produced a blueprint that enables prioritisation and accelerates area development. Nonetheless, working out the specifics of the three selected areas has increased insight into how to approach the development of networks.

5.2 Low-pressure networks needed to connect regional industry

The studies of the various network sections show that alternative 2, which involves only low-pressure networks, is the most favourable option. Low-pressure infrastructure is the most cost-effective, can meet specific customer needs (using boosters), and is quicker to build than high-pressure infrastructure. The only exceptions to this are a small number of customers who need high volumes and/or high pressure ratings and who are located near the national hydrogen network.

Ultimately, there are more considerations than just cost that play into the choice of one network development option over another, including the availability of sufficient capacity in the long term. Allowances will also have to be made for these kinds of aspects in drawing up a development plan for regional hydrogen infrastructure. A well-chosen combination of high-pressure and low-pressure infrastructure will, therefore, be the best option to be able to supply regional industry with hydrogen. This will require collaboration between the operators of high-pressure and low-pressure infrastructure, so that they will be able to develop and optimise networks based on capacity, pressure, distance and cost.

6. Next steps

In the future energy system, hydrogen will play a crucial role - it will be indispensable. Regional hydrogen networks will be needed to support timely and cost-efficient decarbonisation of regional industry. What is currently lacking is scope for action for regional hydrogen development, which is a point that was also raised by Cluster 6 in its recent publication.[6] The network operators are seeing that regional companies, but also provincial and local authorities, want to get started with hydrogen, and are launching projects for it. At the same time, however, the lack of clarity on how the hydrogen market will be organised and what roles this will involve means that it is impossible to say at this point whether it will be possible to connect such decentralised hydrogen networks to the national network in the long term. Additionally, the national network is not yet up and running and hydrogen production has not yet started, as both are still very much in the development phase. Regional development of hydrogen is conditional on collaboration across all stakeholders and in particular between the network operators and the Ministry for Climate Policy and Green Growth.

The network operators recommend the following next steps:

1. Develop the first regional case studies.
2. Draw up a development plan for regional hydrogen infrastructure.
3. Clarity on market regulation.

6.1 Develop the first regional case studies

Hydrogen for regional companies will be a new constituent part of the Netherlands' energy system. As with any new development, developing it involves conducting studies, running pilot projects and performing experiments. Network operators, authorities and companies will go through a learning curve. However, there is no need to put this off until there is greater clarity on the ultimate size of the hydrogen market in the Netherlands. The learning curve can start now by conducting the first case studies. This is possible only when the parties involved work together:

- The Ministry of Climate Policy and Green Growth will have to designate a network operator to operate the networks in these areas.
- Hynetwork will have to take care of connecting the regional networks to the national network, either from the start or in the longer term.
- The regional network operator in each area will have to organise collaboration with their stakeholders, i.e. regional companies, provincial authorities, local authorities, etc.

As soon as this learning curve is underway, lessons will be learnt that can be harnessed in further developments with regional hydrogen systems.

6.2 Draw up a development plan for regional hydrogen

The development of hydrogen is still highly uncertain. It is not yet possible to estimate hydrogen consumption volumes and tariffs for the coming decades with any kind of precision. There are two ways we can deal with that: we can wait until we know more or we can keep working based on the view that hydrogen is indispensable for Cluster 6 companies. The network operators prefer the second option, bolstered by the regular requests they get from regional companies to work together on low-pressure

[6] publication - *Cluster 6 lanceert Landelijke Cluster Energie Strategie* [Cluster 6 launches National Cluster Energy Strategy]

hydrogen. What will be needed to scale up after the first case studies is a development plan from the government and network operators that offers regional industry a realistic prospect that hydrogen will actually be supplied. The development plan will provide insight into when and how hydrogen will arrive in the various regions, i.e. how regional networks can be developed and within what timespan. The following ongoing studies and initiatives will be used as input for this plan: HyRegions 1, this HyRegions 2 study, provincial Energy Visions, pMIEK projects, Cluster Energy Strategies (CES), municipal heating programmes, etc. This regional development plan will be consistent with the Hynetwork roll-out plan and based on assumptions or bandwidths regarding hydrogen demand and production. In addition, it will also consider potential needs from the perspective of the integral energy system and sectors that are hard to rid of emissions. In the future, the plan will require constant updating with the most recent insights and lessons learnt.

6.3 Clarity on market regulation

The previous section outlined that a development plan is the next step towards scaling up regional hydrogen. However, such a plan can only be drawn up if it is clear who will be doing the developing. On a broader scale, this applies to hydrogen supplied at low pressure: the network operators foresee that without clarity on who will be given that task, regional hydrogen will not get off the ground. The Ministry of Climate Policy and Green Growth will have to appoint one or several parties that will, on an exclusive basis, be tasked with building the low-pressure infrastructure. This will create clarity for regional industry and steepen their decarbonisation rate. For the national hydrogen network, the market was formed in 2022, which brought the kind of clarity that we have already seen lead to initiatives and projects along the route of the national network. This kind of clarity is lacking when it comes to regional distribution systems, meaning that regional industry has no clarity either, while these regional networks will be ready within approximately 7 to 10 years. An exclusive statutory duty will, therefore, have to be assigned to give regional industry scope for action.

An often-heard concept in relation to the development of energy infrastructure is ‘a level playing field’, i.e. fair and equal access to energy to prevent market distortion for industry. To achieve a level playing field for regional hydrogen, clarity is needed on how the market will be organised. Having been assigned a statutory duty will enable the designated party or parties to treat companies equally in comparable situations, regardless of where in the Netherlands they are based. Such an appointment will allow the ministry to ensure that the social interest is pursued.

The lack of clear market regulation may have the following consequences:

- Without clarity on market regulation, the legislator will not be able to impose an obligation on any party to develop a hydrogen distribution system in certain areas. Only once a network has been completed will the statutory duty to connect consumers to it become applicable, meaning that potential customers in areas without a network cannot claim a connection. This disrupts the level playing field for regional industry.
- It leads to a number of coordination issues, including the following:
    - Hynetwork will have to engage with all potential distribution system operators, instead of having one single point of contact.
    - Authorities do not have a clear-cut party that represents hydrogen on a regional level in energy issues, energy planning, energy boards, etc.
    - System integration between various forms of energy becomes increasingly challenging. Grid congestion requires us to make choices as a society, because while a hydrogen network may not be financially balanced in itself, it may still be (a lot) cheaper than upgrading the power grid.

- Harmonisation of tariffs is not possible. Without an exclusive statutory duty assigned, there will be regional differences in tariffs for the hydrogen network.
- There is a risk of cherry picking, which would see only attractive areas connected to the national network, thus hampering a level playing field.
- Parties may choose to wait and see: developing regional hydrogen may not be attractive commercially or only moderately attractive, causing it to not get off the ground.
- The heat infrastructure situation may repeat itself: commercial parties build hydrogen infrastructure and a future government decree that infrastructure must be publicly owned leads to the same costs, delays and chaos we are currently seeing with heat networks.