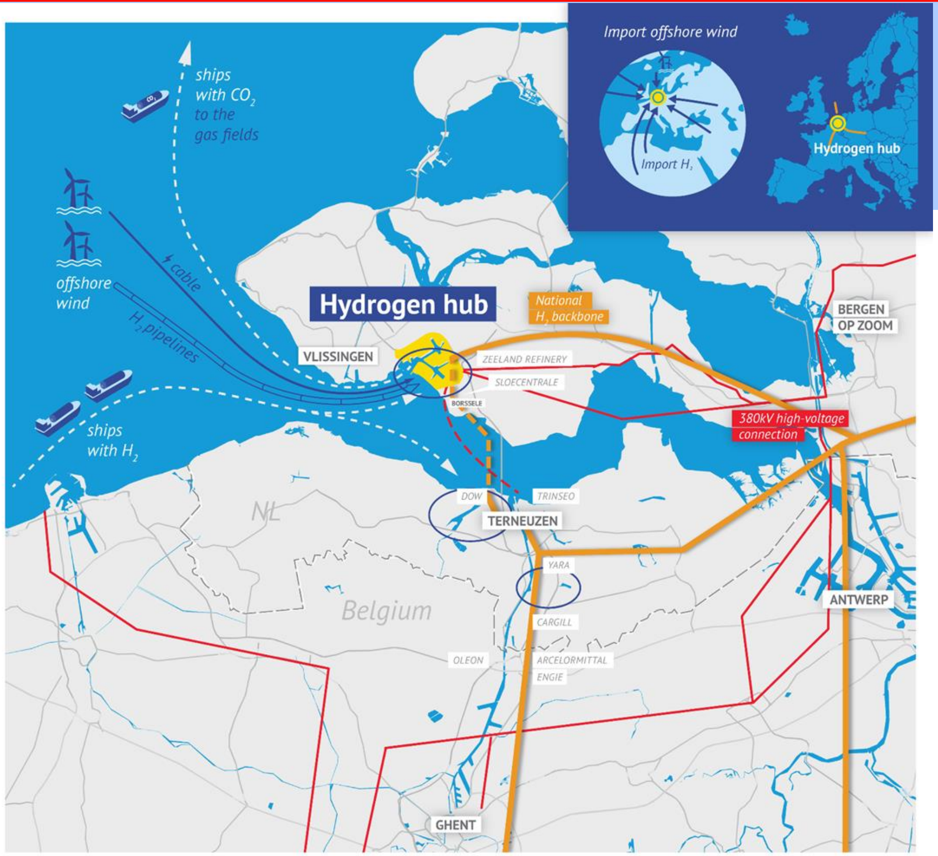

CE Delft
Committed to the Environment
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Potential for Hydrogen hub Schelde-Deltaregion

Management summary

Commissioned by:
Smart Delta Resources

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1 Management summary

Background and methodology

The Smart Delta Resources cooperation platform* (SDR) is working together to achieve substantial CO_2 reduction in the industrial cluster of the Schelde-Deltaregion. One of the key transition paths is the Hydrogen Delta Program, aiming to make hydrogen more sustainable (green and blue hydrogen transition path). As part of this SDR conducted an exploratory study into the potential hub function of North Sea Port for clean hydrogen (carriers). This study indicates whether, in what form and to which extent the Schelde-Deltaregion is suitable for large-scale clean hydrogen import, export and transit.

To determine the potential hub opportunities for the Schelde-Deltaregion, a start was made with determining the market potential for import and transit of hydrogen with three integral scenarios for the years 2025-2030-2035-2040 (including a glimpse into 2050): Regional, National/European and International. The scenarios involve local demand, demand in the nearby region and demand in the further hinterland for various potential hydrogen carriers (molecules). For the use of hydrogen in the hinterland, it has been assumed that the transit is through pipelines. Conversion of hydrogen carriers to hydrogen takes place in the North Sea Port. Only those hydrogen carriers that are used as "feedstock" by the industry are used as molecules or transferred to the hinterland (e.g. methanol, e-methane or ammonia).

In order to determine the import or export potential, the local production capacity for green hydrogen was mapped. The final import requirement and export potential results from the balance between the local expected production and the total expected demand. To ultimately determine what a hydrogen hub will look like, the hydrogen carriers were assessed based on a cost price analysis, to determine which are the most plausible to be used for import to the North Sea Port and from which countries that will occur.

For the two most promising hydrogen carriers it was then determined what the logistic chains will look like with regard to transport by ship, storage, transhipment and reconversion. Because of the current state of technology and the market, it is not yet possible to determine which of these hydrogen carriers will ultimately be used. It will probably be a combination of hydrogen carriers. For this reason, the hub definitions in this report assume that the total import volume will be imported via one type of hydrogen carrier. Thereafter a comparative analysis is conducted to examine the competitive position of North Sea Port in comparison to the ARA-ports (Ports of Amsterdam, Rotterdam and Antwerp) for the development of a hydrogen hub.

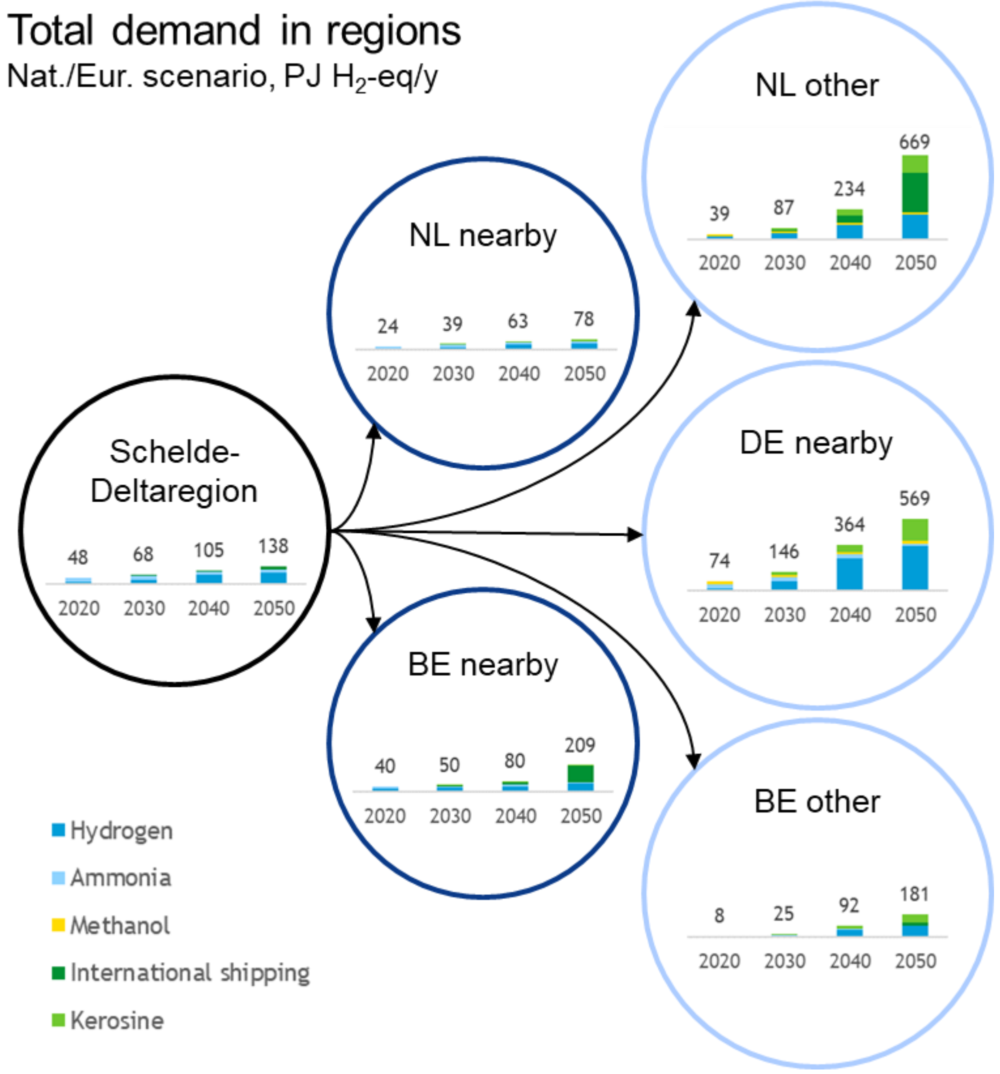
For the activities that could take place in the Nort Sea Port, the expected space requirements were determined and possible locations were mapped. This helped to develop a definition of what a potential hydrogen hub in the Schelde-Deltaregion might look like. Based on this hub definition, a rough estimate was made of how many jobs such a hydrogen hub would generate for the region and what the added value of this would be for the region.

To conclude the study, the role of a hydrogen exchange on the development of a hydrogen hub and the role that SDR-parties can play in this process were examined.

[1] *SDR is an industrial partnership with the following members, Air Liquide, Air Products, ArcelorMittal, Cargill, Cosun, Dow, Engie, Fluxys, Gasunie, Lamb Weston Meijer, Ørsted, PZEM, Trinseo, Yara, Zeeland Refinery and Vopak. SDR is actively supported by Provinces of Zeeland and East Flanders, North Sea Port Trines Authority and Economic Impulses Zeeland.*

Market potential: H_2-demand, H_2-production and H_2-imports

The Schelde-Deltaregion has a **unique** position to develop into a hydrogen hub. The region with the ports of Vlissingen, Terneuzen and Ghent **has the largest industrial hydrogen cluster of the Benelux** (70 PJ/y, 580 kton/y), with companies such as Yara, ArcelorMittal, Dow and Zeeland Refinery. Because of the sustainability tasks, these parties will ensure a basic demand for hydrogen and/or hydrogen carriers which they will use as feedstock or fuel. The total demand from the region grows in different growth scenarios (Regional, National/European and International) from between 65 and 75 PJ/year in 2030 to 70 and 180 PJ/year in 2050. The demand for hydrogen is also growing in the hinterland of the North Sea Port as a result of sustainability. The demand from the hinterland of North Sea Port (e.g. from industrial clusters such as Antwerp, Chemelot, the German Ruhr and Rhine-Main area) is growing from 380 PJ/y in 2030 to 1100 to 2300 PJ/y 2050 (see figure on the righthand side).

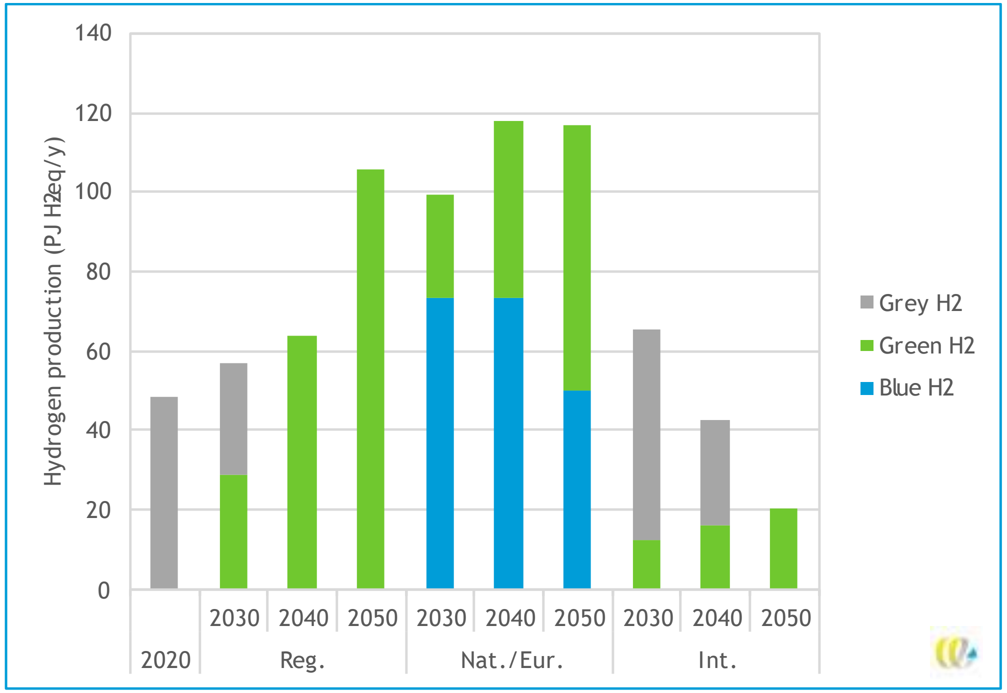


The graph below shows the total projected volumes of hydrogen produced in the Schelde-Deltaregion. The total production capacity in 2050 in the Regional and National/European scenarios is 2-2,5 times the current production capacity, while local production declines by about 60% in the International scenario.

Recently, several concrete plans (medium/long-term) for green hydrogen production in the region have been identified (up to 2040 a total of 4.2 GW (45 PJ/y, 320 kton/y)) as well as one project for new blue hydrogen capacity.

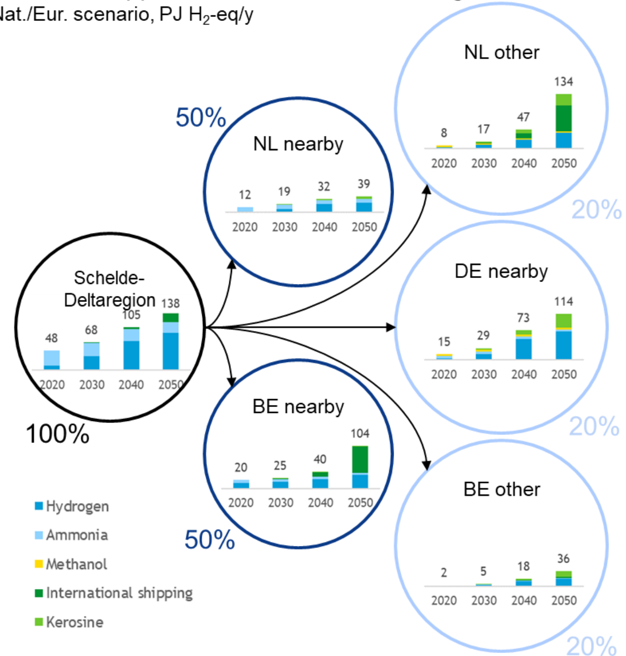
Depending on the growth scenario, the demand for green hydrogen already exceeds local production by 2030 (or else in the longer term). Import is therefore important not only because of the demand volume, but also for the reliability of hydrogen supply. Despite competition from other ports, it is expected that the North Sea Port can play an important role in the supply of hydrogen and hydrogen carriers. The volume expected to be supplied through the North Sea Port is between 100 and 105 PJ in 2030 and grows to between 280 and 570 PJ in 2050 (see figure on the right side).

Hydrogen production in Schelde-Deltaregion



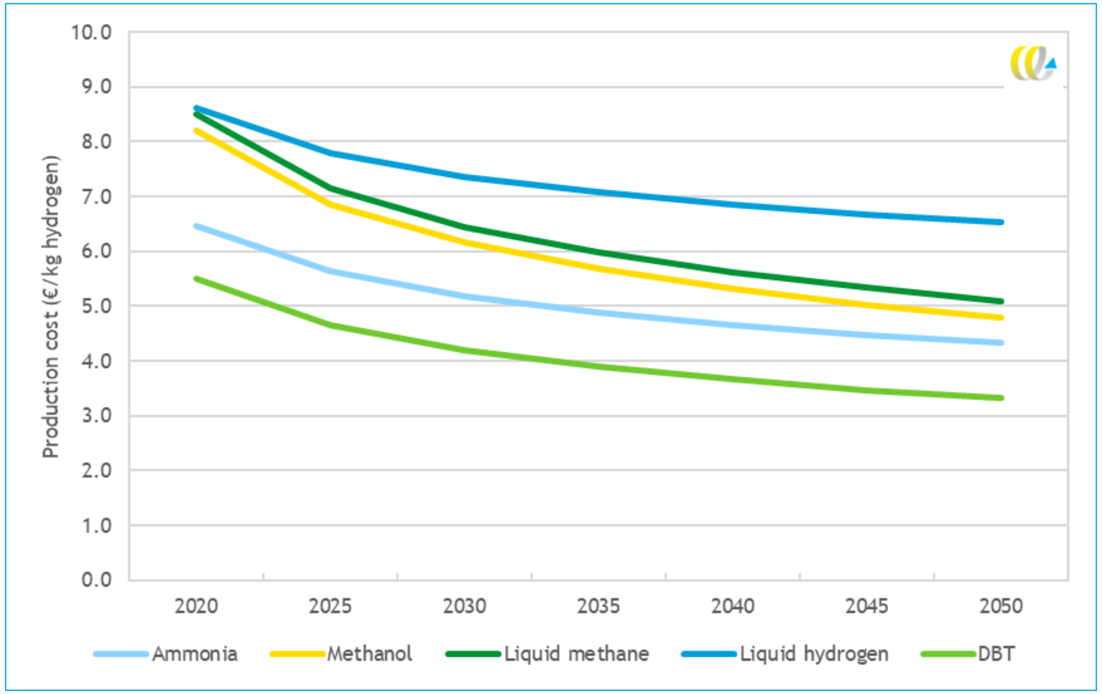
Demand supplied from Schelde-Deltaregion

Nat./Eur. scenario, PJ H_2-eq/y



Percentages show the supply from the Schelde-Deltaregion as a share of the total regional demand.

Production cost of imported green hydrogen by means of different hydrogen carriers in the ‘Average’ scenario

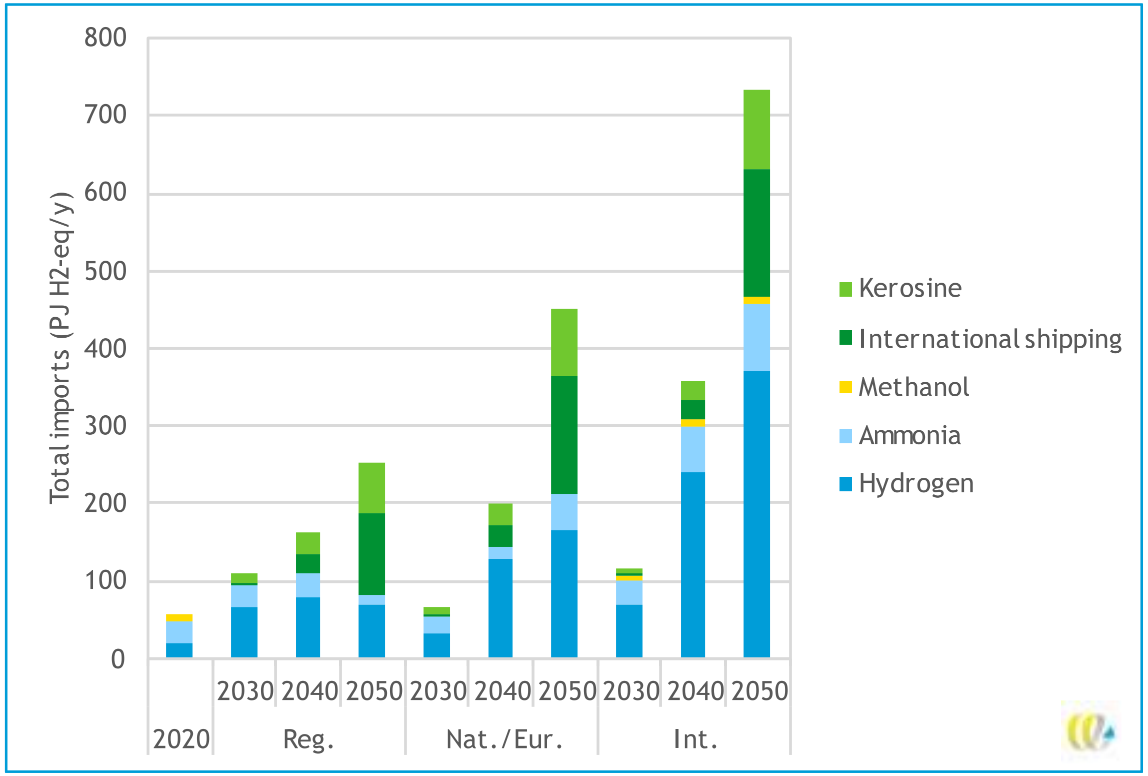


Note: The production cost includes the costs of production, (re)conversion, storage and transportation.

In particular, imports of hydrogen carriers such as **ammonia and dibenzyltoluene** (DBT) are suitable for the Schelde-Deltaregion. This is because their product cost are lower (see figure above) compared to other hydrogen carriers, the existing home market and the already existing infrastructure in the region that can be used for these molecules. Morocco and Saudi Arabia appear as countries from which these molecules can be imported cheaply. However, the production cost of imported green hydrogen is mainly driven by the choice of the hydrogen carrier, more than by the choice of the country of origin.

Projected import volumes vary from 65 to 115 PJ/y in 2030 (0.5 - 1 Mton H2-eq/y) and 160 to 360 PJ/y in 2040 (1.3 - 3 Mton H2-eq/y). In some growth scenarios, local production exceeds local demand and a surplus of locally produced green hydrogen emerges. This surplus can then be exported from the Schelde-Deltaregion to the hinterland. However, whether a surplus emerges is uncertain.

Total potential for import per molecule

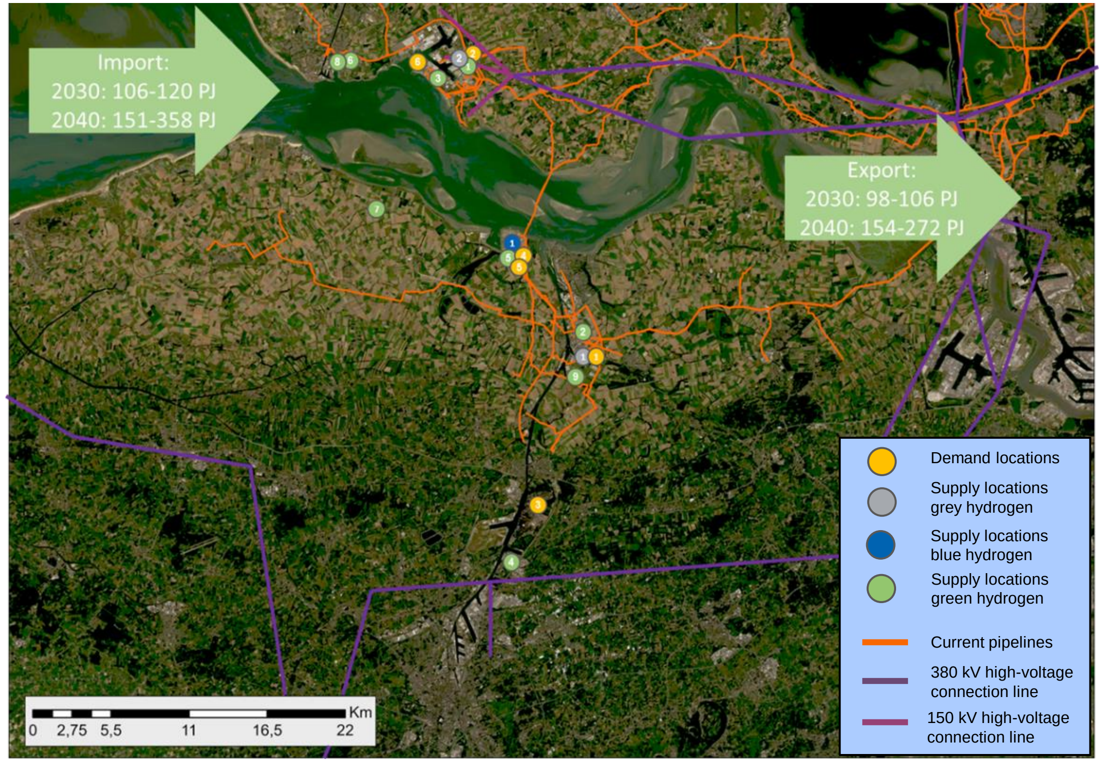


H_2-Hub Schelde-Deltaregion

The Schelde-Deltaregion **has already a basic infrastructure** in place which can be used directly to handle import flows of hydrogen carriers such as ammonia and DBT (a LOHC). Existing storage terminals for fossil fuels and chemicals in the North Sea Port, but also existing storage capacity for ammonia, can be used initially. Also, companies like Yara might be able to use their plants and flexibly import green ammonia and then flexibly use existing SMRs for hydrogen production that they feed into the backbone. This flexible use of assets is a unique combination in this region. With these import possibilities offered by the existing infrastructure and the planned production plans, the Schelde-Deltaregion can already develop its **home market for green hydrogen** in the short-term, taking a first step towards becoming a hub.

There are various locations in the region (including Vlissingen, Mosselbanken, Axelse vlakte) where growth of storage, transshipment and reconversion of hydrogen carriers is possible. Where the actual facilities will be established depends on the commercial considerations of the parties involved. The competitive position of North Sea Port compared to other ARA ports is good in several respects: there is **sufficient room for growth**, **land prices are relatively low** compared to the other ARA ports, there is a **good home market** and **availability of the necessary infrastructure**. This allows the Schelde-Deltaregion to position itself well as a hydrogen hub.

Current and future infrastructure in the Schelde-Deltaregion



A hub definition has been developed for the two hydrogen carriers most suitable for import (Ammonia and DBT) (see figures on the right).

Ammonia hub*

To handle import volumes expected under the various growth scenarios, ammonia is expected to require between 140 and 240 ship movements per year in 2030 and between 260 and 530 in 2040. In addition, storage and reconversion will require roughly 30 hectares in 2030 and roughly 70 hectares in 2040.

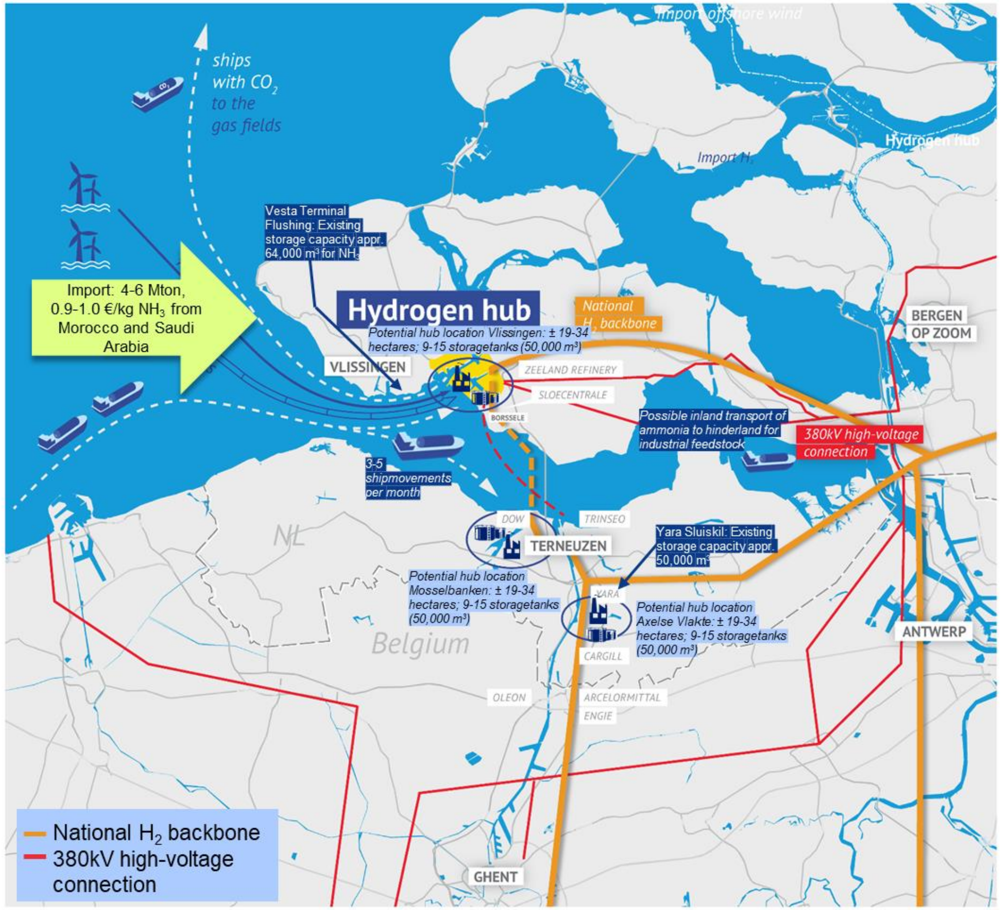
DBT hub*

To handle the expected DBT import volumes, between 260 and 460 ship movements per year are required in 2030 and between 690 and 1430 ship movements per year in 2040. In addition, a space requirement of 130 hectares in 2030 and 300 hectares in 2040 is foreseen for the storage and reconversion of DBT (if the entire storage capacity has to be newly built).

The hydrogen is transported to the hinterland via the hydrogen backbones. It is expected that a very limited part of the hydrogen carriers will be transported to the hinterland in the form of the carrier molecule. Ammonia will then be transported primarily by inland shipping. Rail transport is possible only to a very limited extent, because the “Basisnet law” imposes limits on the volume transported. Pipeline transport of ammonia from the North Sea Port seems less likely. This would require a large buyer/customers at one location that can guarantee a continuous flow of volume for a long period of time. DBT is not transported further inland but is converted to hydrogen directly at the port. In fact, the DBT molecules which are not "loaded" with hydrogen are transported back to production sites after reconversion.

Methanol, because of its higher cost and the complexity regarding international CO_2 return flows, is expected to be used only as a molecule by industry and less likely to be used as a hydrogen carrier via the North Sea Port. Import of methanol will then go through the already existing channels (pipeline and inland shipping).

Potential hub design – Ammonia (reference year: 2030) **



** For the analyses, it has been assumed that the total import volumes are imported through one type of hydrogen carrier. In reality it will be a combination of hydrogen carriers. The mix of these hydrogen carriers cannot be predicted at this time.*

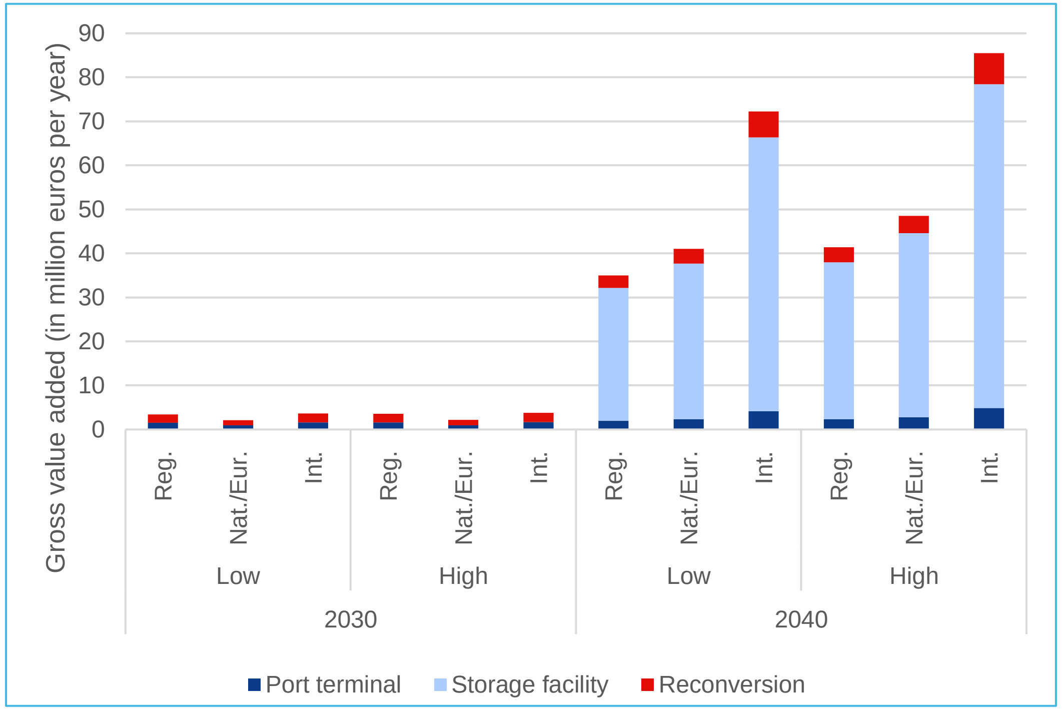
*** The potential hub design for DBT is included in the mainreport.*

The Schelde-Deltaregion is **strategically located** in relation to the planned **hydrogen backbones in the Netherlands and Belgium**. A connection to the Dutch and Belgian backbone is planned. Gasunie and Fluxys are also working together to connect the Belgian backbone and the Dutch backbone. With that, the Schelde-Deltaregion will immediately have a very good connection with the more distant hinterland in the Netherlands, Belgium and Germany. This connection is a precondition for importing even larger volumes of hydrogen carriers via the North Sea Port.

To take the hub a step further, it is important that various locations where hydrogen carriers will be converted to hydrogen (reconversion) and the locations where hydrogen will be produced with green electricity are connected to each other via a regional pipe infrastructure. Such a regional backbone, with open access, will enable even more parties to purchase and supply hydrogen. This will strengthen the further growth of hydrogen imports and use and with that the hub position of the Schelde-Deltaregion.

When the Schelde-Deltaregion becomes a hydrogen hub, it will generate one-time employment for the construction of facilities and structural employment for the new hub activities that will come to the region (terminal activities, management, operation and maintenance of the storage and reconversion facilities). Based on expert estimates and CE Delft studies*, this will result in 240 to 410 FTEs in 2030 and 380 to 790 FTEs in 2040 in one-time employment and 20 to 35 FTEs per year in 2030 and 370 to 770 FTEs per year in 2040 in recurrent employment. These activities generate an economic added value for the region of approximately €20 million to €40 million per year in 2030 and approximately €80 million to €165 million per year in 2040 (depending on the different growth scenarios and type of employment). The gross valued added of recurring employment is displayed on the graph on the righthand side of this page.

Gross value added of recurring employment per component (port terminal, storage facility and reconversion) of the hydrogen hub



** Source: CE Delft (2021), Werk door investeringen in groene waterstof: Update en uitbreiding*

When hydrogen will be used more and more, there will be a trade in this fuel and feedstock. A hydrogen exchange will be created for this purpose, where supply and demand will be matched. The introduction of such a hydrogen exchange can stimulate the use and supply of green hydrogen and strengthen the growth of a hydrogen hub. The development of an exchange is already being taken up nationally and internationally. The SDR-partners must remain on board. An important precondition for the import of hydrogen and hydrogen carriers is that the certification of green molecules is properly regulated, both nationally and internationally.

Based on the analyses and interviews conducted, the following **recommendations** for the SDR-partners are made:

- The "first-mover" advantage is high in the development of a hub and that will be no different for hydrogen. It is therefore important that steps are taken in the short-term to make that hub possible. An important step is for SDR-partners to make concrete agreements with export countries/export parties for the supply of the hydrogen carriers to the North Sea Port in order to get the import of hydrogen off the ground. SDR and the North Sea Port authority can take a facilitating and initiating role in this. Parties should start working on this at board level (Chefsache!).
  - When Letters of Intent are concluded with export parties, it will become clear which hydrogen carrier will be used. The Schelde-Deltaregion has the right infrastructure to handle most hydrogen carriers. Ammonia and DBT seem to be the most obvious molecules.
- Within the Schelde-Deltaregion there is a lot of complementarity to get the import hub off the ground, such as existing asset owners, energy traders, hydrogen and ammonia customers, terminal and pipeline operators. This platform offers excellent opportunities to use this exploration to make concrete next step towards realisation of the necessary infrastructure in the region.
- Import does not have to be a threat or competitor of local green hydrogen production. It is more likely that import has a strengthening effect on the local production chain. Since local production will not run continuously, imports are necessary to provide the industrial base load and to establish a robust chain.
- Stimulate with the SDR-partners the certification of green hydrogen carriers, by actively participating in pilots and (inter)national working groups.
- The combined space requirements of import, storage and reconversion are large and will grow towards 2040 as import flows increase. To avoid fragmentation and thus waste of space; there will be a proactive role for North Sea Port.
- Importing large volumes of ammonia can still lead to safety debates and public opposition despite greatly improved external safety. The possibilities of increasing ammonia shipping on the Schelde need to be further investigated and discussed with stakeholders such as the Ministries of Infrastructure and Water Management and Economic Affairs and Climate, municipalities and provinces*.
- The discussions about connecting the North Sea Port to the national hydrogen backbone must continue unabated. Part of this is to see whether specific companies should be connected to the regional hydrogen infrastructure, so that hydrogen can be supplied and purchased regionally (creating a regional backbone).

** The status of the "Scheldeconvenant" was not examined in this study*