

Tanktainer pool document

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Related documents	Appendix A

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1. Introduction

RH2INE stands for Rhine Hydrogen Integration Network of Excellence and was established in 2019. It is the multi country initiative to accelerate Hydrogen for inland shipping. As spin off from this initiative the Condor H2 project was set up in 2022. In this project over 30 value chain partners cooperate to realize the first hydrogen ships. Based on previous work and reports, such as the “RH2INE Kickstart Study” and during the development of Condor H2 it became clear that:

1. Hydrogen should be supplied to the ships in containerized tanks (tanktainers) and
2. It will be optimal to establish a (not for profit) neutral entity that organizes the operations and the logistics of the tanktainers (the Tanktainer company).

This document gives an overview of the topics discussed in the “Tanktainerpool Company working group” of the Condor H2 project on the activities, responsibilities initial funding and potential growth of the Tanktainer company. Parties that joined this working group are:

- Engie
- Linde
- Roger Energie
- Rotterdam Shortsea Terminal
- HTS Maritime
- VT Group
- Rabobank

2. Goal of the tanktainerpool

The goal of the tanktainer pool which was agreed in the Condor H2 working group was:

To enable the use of tanktainers by the shipping sector at the lowest cost possible

During the first workshop it was discussed why a shared and central pool of tanktainers was necessary to achieve the goal above.

- Investments:
 - No investment needed from the shipowner
 - Easier to finance a pool than each tanktainer separately
 - Easier to get subsidies for a pool (depending on entity / set-up)
 - Fewer tanktainers needed per ship (on average)
- Logistics:
 - Higher utilization rate per tanktainer
 - Reduced cost due to logistic optimization- less transportation
- Reduced operational / administrative costs due to centralisation
- Centralized expertise

This means we aim to lower the amount of tanktainers that is needed per ship by pooling tanktainers with other users. By sharing the tanktainers there use can be optimised (transport, filling, etc.) resulting in a lower average amount of tanktainers that is required per ship.



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3. Definition responsibilities company

3.1 Activities and roles

Below the possible roles and activities of the tanktainer company are shown, they are divided in: minimal activities; optional activities and activities that are to be decided up on.

Minimal activities

1. Logistical data/digital aspects for optimal utilization
 - Determine swapping locations
 - Determine optimal filling location
 - Determine when to fill/leave empty tanktainers
 - Monitoring H₂ storage quantities at locations (maximum capacity of locations)
2. Organise the physical logistics of the tanks (*to be contracted to a logistics company*)
 - Transport
 - Swapping
3. Communication/coordination
 - With H₂ suppliers/filling locations
 - With ships/shipping companies
 - 3rd parties (logistical partners)
4. Technical data/digital aspects
 - H₂ quantity monitoring in the tanks & define the standard for this
 - Data/monitoring regulatory topics
 - Data for preventative maintenance
 - Data H₂ quality monitoring/contracting
5. Tanktainer company operations (order to cash)
 - Exploitation (admin & billing)
 - Company operations
 - Business development/sales

Optional activities

6. Ownership of tanktainers (asset company/leasing company)
 - Finance the required tanktainers
 - Acquire required tanktainers
7. Maintenance & certification
 - Arrange maintenance services
 - Ensure required certification of tanktainers

To be decided upon

- Hydrogen supply, contracting the hydrogen, **or**
- Only the administration of H₂ usage & residue

3.2 Hydrogen contracting and administration of residue

One of the challenges with using tanktainers across hydrogen suppliers and across ships/ shipowners is that gaseous hydrogen tanks are never 100% empty. A tanktainer never will be completely emptied, this is physically not possible. Therefore, each tank will always have a minimum amount of hydrogen in the tank (+/- 10% of the full capacity).

During the working group sessions, a lot of time was spent discussing the two main options to manage the hydrogen in the tank, the measurement of the residue and the invoicing of the hydrogen and residue.

A number of parties were of the opinion that the tanktainer pool cannot work effectively if it does not also contract the hydrogen for the shipowners. The key reason here is the management and invoicing of the residue. So, when a tank is removed from a ship, there will always be residue from the previous times it was filled. This residue has a certain value and quality.

There is still discussion if the tanktainer company should also buy the hydrogen or only administer the usage and the residue. To give more insight in the discussions that were held during the workshop the figures below were added for a complete overview of advantages and disadvantages of the ownership of hydrogen by different parties go to 8 Appendix A.

H2 flows- Scenario: tanktainer company owns H2 in tanks

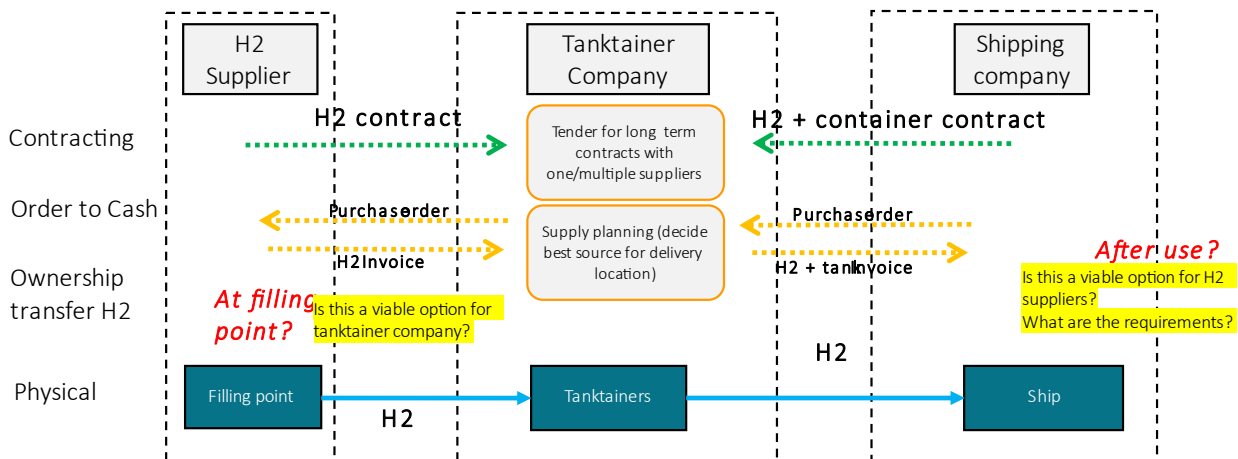


Figure 1: Tanktainer company owns hydrogen in tanks

In Figure 1 the schematic case where the hydrogen supplier will take over the ownership of the hydrogen at the filling point at the hydrogen supplier. This is the most favourable option according to most H2 suppliers. This way they do not have to conclude contracts with all the different shipping companies that do not have experience with contracting H2. This saves time, and furthermore there is a credit risk when dealing with a single shipping company.

H2 flows- Scenario: Hydrogen supplier owns H2 in tanks

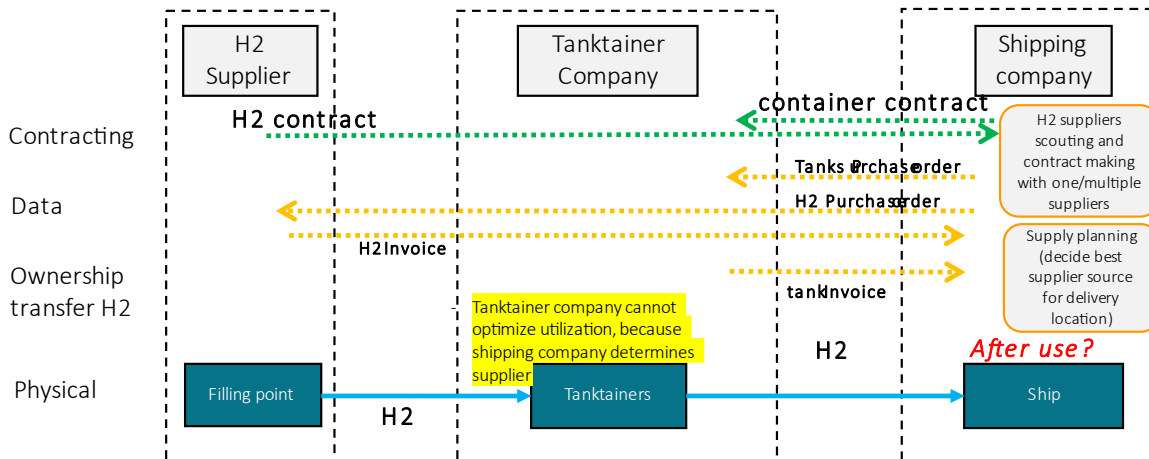


Figure 2: Hydrogen supplier owns hydrogen in tanks

Figure 2 is the scenario where the supplier owns the hydrogen in the tanks until it is being used by the shipping company. The ownership of the hydrogen is transferred at the use onboard the ship. This gives the shipping company the control to conclude their own contracts with hydrogen suppliers without a tanktainer company. For the tanktainer company this makes it more difficult to optimize utilization because the shipping company determines the supplier.

Hydrogen supplier are not in favour of this option, because it increases the risk to them.

H2 flows- Scenario: shipping company owns H2 in tanks

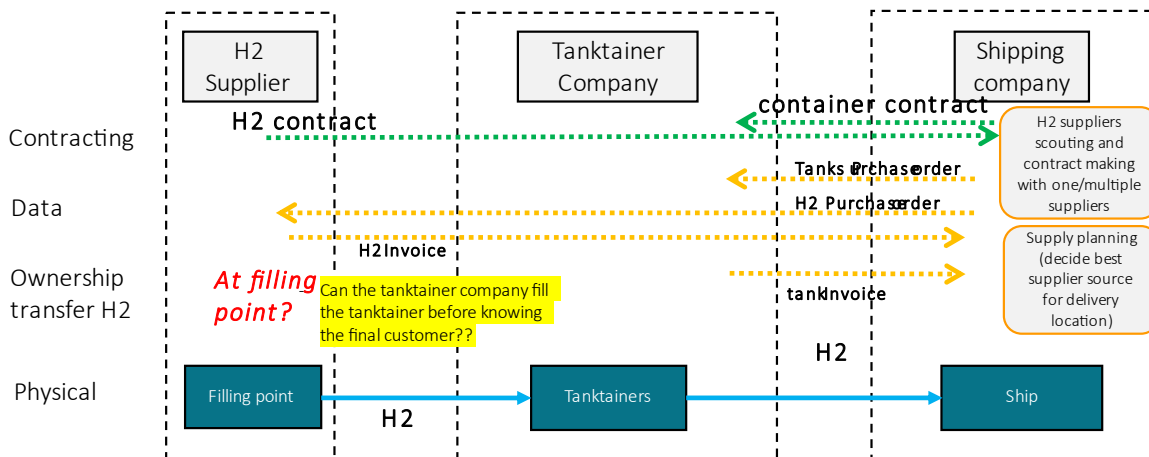


Figure 3 shows the scenario where the shipping company owns the hydrogen in the tanks – which gives the freedom to choose the hydrogen supplier. A very precise planning from the shipping company, tanktainer company and hydrogen supplier is needed to ensure that the right tanktainer, with hydrogen goes to the right place. The ownership of the hydrogen is transferred at the filling point at the hydrogen supplier.

From discussions, the group concluded that the second and third model do not give the suppliers and shipping companies enough benefits of the tanktainer pool that is created. Because the tanktainer company is not able to optimise the demand for hydrogen and the best place to fill the tanktainers. There is also a problem if there is any residual hydrogen left in tanktainer bought for a certain price and it is filled up again at a different price. Who will pay for the residue?

The first option is the most favourable situation for the hydrogen suppliers in that way the credit risk – because of a higher demand – is better and they do not have to conclude multiple contracts with shipping companies that do not have any experience with the buying and selling of hydrogen.

There where however some remarks from shipping companies that they rather buy their own hydrogen – and not in a purchasing cooperation. But because the demand of the shipping companies in the first years will be low it is probably beneficial to buy hydrogen in a purchasing company at least for the first few years.

In Table 1 the activities and roles of the tanktainer pool company are elaborated in more detail with who will take the lead, who will execute and who will support in setting it up.

Table 1: Activities tanktainer pool company – scenario sourcing by Tanktainer pool company

Activities	To do's	Who will take lead?	Who will execute?	Support in setting it up
Logistical planning for optimal utilization: data/digital aspects	<ul style="list-style-type: none"> Determine swapping locations Determine optimal filling location Determine when to fill/leave empty Monitoring H2 storage quantities at locations (maximum storage capacity) 	Logistics company (e.g. Schenk, Hoyer), tanktainer company, Hydrogen Flow	Logistics company (e.g. Schenk, Hoyer), Hydrogen Flow	Distributors, H2 suppliers (e.g. Engie, Roger, Linde, Air Products)
Execute the physical logistics of the tanks	<ul style="list-style-type: none"> Transport Swapping Ensuring certified personnel 	Logistics companies, H2 suppliers, Terminals (RST, HTS, etc.)	Logistics companies, H2 suppliers, Terminals (RST, HTS, etc.)	Logistical parties
Communication/coordination:	<ul style="list-style-type: none"> With H2 suppliers/ filling locations With ships/ shipping companies Logistical parties 	Tanktainer company, logistics company	Tanktainer company, logistics company	
Technical data/digital aspects*	<ul style="list-style-type: none"> H2 quantities monitoring regulatory topics (leakage etc.)* quality monitoring preventative maintenance H2 certificates (carbon 	H2 suppliers (during filling), Tanktainer pool company (standardisation),	Tanktainer pool company	Metering company, software supplier, (EkInetix)



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Activities	To do's	Who will take lead?	Who will execute?	Support in setting it up
	insetting)			
Tanktainer company operations (order to cash):	<ul style="list-style-type: none"> Exploitation (admin & billing) Company operations Business development/ sales 	Tanktainer company	Tanktainer company	<ol style="list-style-type: none"> Contracting hydrogen (H2 suppliers and shipping companies) Operation (logistical party)
Ownership of tanktainers (asset company/ leasing company):	<ul style="list-style-type: none"> Finance the required tanktainers Acquire required tanktainers 	Bank (e.g. Rabobank), H2 suppliers, Ship owners, Schenk, Hoyer, Trifleet, Den Hartog, Container construction companies financiers, impact investors (<i>keep in mind it is an enabling company</i>)	Investors	Tanktainer company, (Consortium)
Maintenance & certification:	<ul style="list-style-type: none"> Arrange maintenance services Ensure required certification of tanktainers 	Logistical parties	Veritas, Lloyds, DNV, KIWA, UMOE, container manufacturing companies	Logistical parties
Hydrogen supply	<ul style="list-style-type: none"> Hydrogen demand pooling Administrating usage Contracting the hydrogen 	Tanktainer pool company	Tanktainer pool company	H2 suppliers

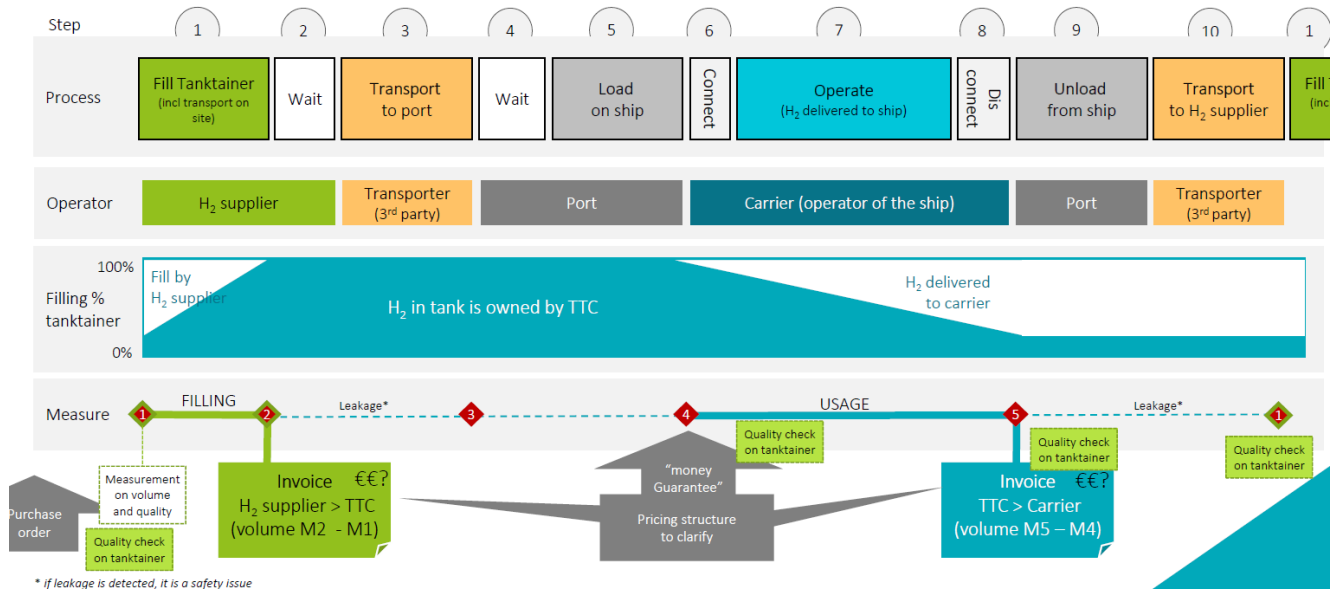
3.3 Organisation structure

When the desired activities and roles are determined, we can start to draft the organisation structure.

At least the functions: H2-Procurement, Planning & logistics, Administration & billing will be main building blocks of the tanktainer company.

4. Definition process flow tanktainers

Who owns the Hydrogen? Once in the tank it is the TTC!



Explanatory note to the tanktainer company flowchart (in this example the H₂ is owned by Tanktainer)

The Tanktainer Company (TC) owns the hydrogen from the moment the hydrogen is in the tanktainer. The TC is able, with the help of telemetry, to continuously monitor the amount of hydrogen that is in the tanktainer and determine the exact location of the tanktainer.

Explanation of the steps described in the flowchart can be found below:

1. Before filling the tanktainer the amount hydrogen in the tanktainer is measured and sent to the TC. The tanktainer is then filled at the H₂ supplier. When a tanktainer is filled it is communicated to the TC and transporter (3rd party), the costs are invoiced to TC.
2. After the tanktainer is filled it is stored for the time being on site at the H₂ supplier, onsite transport is done by the transporter/H₂ supplier.
3. TC directs the logistical partner where the tanktainer is needed to be. The transporter collects the tanktainer and transports it to its destination.
4. The tanktainer is stored onsite of the terminal.



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5. The tanktainer is loaded by the terminal operator onto the ship at the terminal.
6. The tanktainer is now on the ship and is connected to the ship, making it ready to sail off.
7. The ship is on its way and uses the hydrogen from the tanktainer – the amount of hydrogen inside the tanktainer is continuously monitored and measured. The ship has contact with the TC where he wants to swap a tanktainer.
8. The tanktainer is disconnected and the amount of hydrogen that is used is recorded in the logbook.
9. The disconnected tanktainer is hoisted of the ship onto the site of the terminal, where it is stored (not shown in flow diagram) ready to be collected by the transporter.
10. The stored tanktainer is collected by a transporter and transported to the H₂ supplier. Where it is stored (not shown in flow diagram) in anticipation of filling.

5. Example case Rotterdam – Duisburg

High-level example Case Ship: 135x17m. 500 TEU. (based on basic info from HTS)

Retour Rotterdam-Duisburg: 15.000 liter diesel, this equals = ± 150.000 kWh (10kWh / liter diesel).

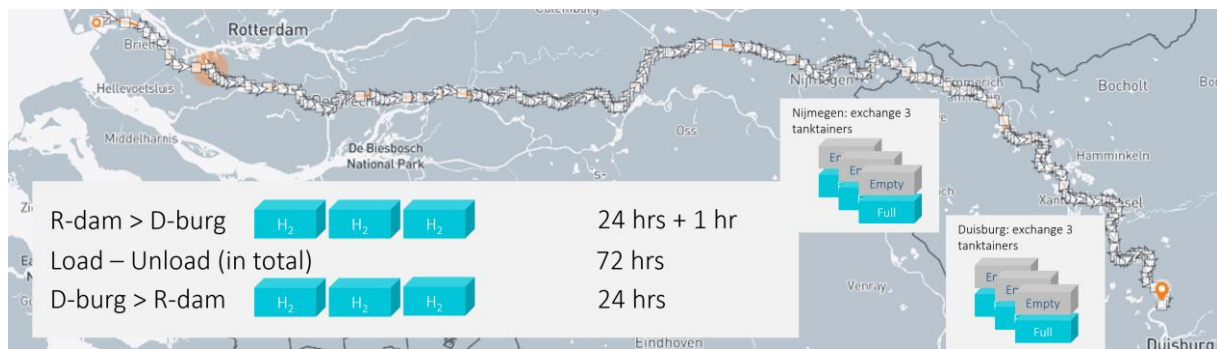
Electric efficiency of combustion engine: 30%. Therefore the needed power is 30% x 150.000 = **45.000 kWh** (45 MWh). Assumption: 2/3 of energy for Rotterdam > Duisburg (30 MWh) and 1/3 for retour Duisburg > Rotterdam (15 MWh).

A H₂ tanktainer contains 342kg H₂ with 33 kWh/kg = 11,3 MWh. Electric efficiency of a fuel-cell = 50%. Therefore a tanktainer contains effectively **5,6 MWh**.

For the trip: $30/5,6 = 5,4 = 6$ tanktainers to D-burg and $15/5,6 = 2,7 = 3$ tanktainers for the return trip.

Total tanktainers needed: 15 : 6 on the ship, 6 in Rotterdam to be filled during the trip and 3 in Duisburg.

Base case



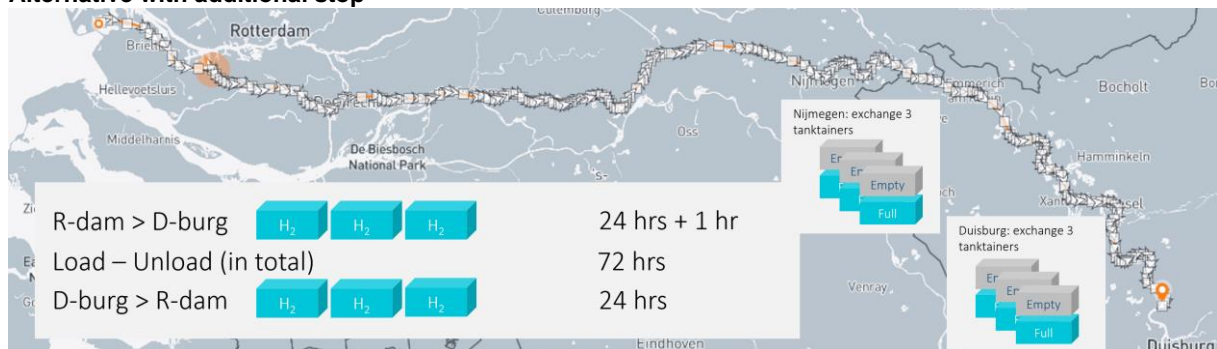
Same case but now the ship sails with only 3 tanktainers and makes additional stop on its way to Duisburg in Nijmegen. Here the 3 empty tanktainers are swapped for full ones.

Total tanktainers needed: 12; 3 on the ship; 3 filled in Rotterdam; 3 in Nijmegen and 3 in Duisburg.

Advantage: Not needed to carry 6 tanktainers all the time (reducing overall containers needed)

Disadvantage: Extra stop in Nijmegen: Time & dependency. Need for Hydrogen in Nijmegen as well.

Alternative with additional stop



6. Entity tanktainer company

A legal entity form must be chosen to establish the tanktainer company. The following chapter discuss what the most suitable form/entity may be for the tanktainer company. In this case it is assumed the tanktainer company is the owner of the hydrogen in the tanktainers.

Requirements

Three important requirements for this tanktainer pool company should be:

1) Enabling

Enable the use of swappable hydrogen tanktainers for the ship owners by offering flexibility for the ship owner, hydrogen supplier, tanktainer investor and make the use of the tanktainer affordable.

2) Transparency

Give insights in the costs and process of swappable hydrogen containers.

3) Service

Remove hurdles like contracting, administrative burden, etc. for the end users, hydrogen suppliers, investors of the tanktainers.

Stakeholders

The most important stakeholders and their relationship with the tanktainer company are shown in Figure 4. The tanktainer company has contracts with:

- H2 supplier, for the supply of hydrogen;
- Logistical provider, for ensuring all logistical movements that are needed between the H2 supplier and the shipping companies;
- Shipping companies, the parties that will use / contract the tanktainers. This can be ship owners or shipping agents (bevrachters).
- Investors; the parties that actually make the capital investments in the tanktainers. The group discussed that the investors in this case are not by definition the tanktainer company, or a specific investment company. Investors could also be H2 suppliers, logistical providers or shipping companies. The tanktainer pool company will conclude contracts with the investors to lease or rent their tanktainers.

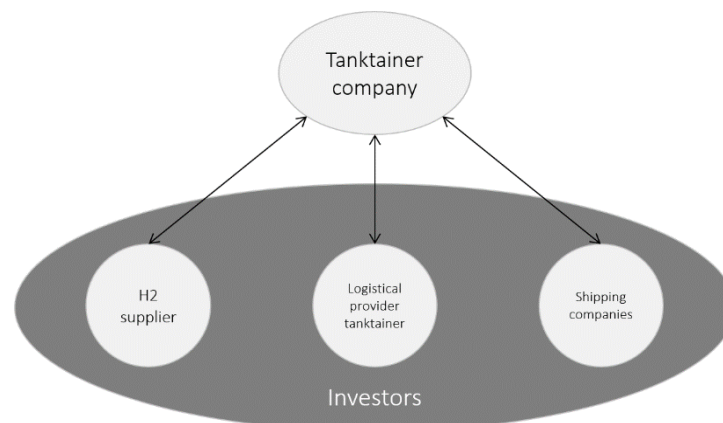


Figure 4: Stakeholders

Entity

Because of the requirements described above the most eligible entity forms are: Private limited company; Cooperation and a Foundation. Some key characteristics of these entities are described in Table 2.

	Private limited company	Cooperation	Foundation
Members and control	Control is in hands of shareholders, share determines control	One member, one vote (vote is not the same as economical investment). Member agreements must be made	No members, control is in hands of the board of the foundation
Board	Shareholders appoint management board, a shareholder meeting is obliged. Supervisory board can be appointed to monitor board of directors	Members appoint management board, a general meeting of members is obliged	Chairman, secretary, treasurer and supervisory board
Business operation	It is an enterprise, revolving about sustainable/profitable operation	It is an enterprise, revolving about sustainable/profitable operation	Idealistic purpose is on the basis of the foundation – profit may only be used for the societal purpose
Joining/leaving	A new partner can join or leave by transferring shares via a notary	Members can join or leave without the intervention of a notary. Rules on joining or leaving are specified in the statutes	No members so only board members can leave. How is specified in the statutes
Dissolution	Shareholders determine to dissolve the entity	Board determines to dissolve the entity	Supervisory board, board (or judge) can dissolve a foundation. How is specified in the statutes
Liability	Limited liability of shareholders	Liability of losses can be specified in articles of association. All profits and losses are shared	Board is not personally responsible
Legal	A private limited company is bound to mandatory legal provisions	Less mandatory legal provisions. Cooperation can be adjusted to own preferences	Profit distributions to founders or directors are not allowed

Table 2: Characteristics entities

Below the pro's and con's are described per form.

6.1 Private limited company (BV)

A private limited company is a business structure with a legal personality. At the start the equity of the company is divided among the shareholders (normally based on the proportion of funding they bring in).

Pro's

- Most known legal structure in corporate world
- Limited liability for the shareholders
- Joined decision making (can also be a con)

Con's

- Changes in shareholder structure always need to be registered at a notary and need majority of shares: adding new or existing shareholders is therefore always a bit of a hassle (and can be costly).

6.2 Cooperative

Cooperative consists of members that can enter or leave the cooperative without jeopardising its continued existence. The control rests with the ALV ('Algemene Ledenvergadering', EN: 'General meeting of members') the ALV can appoint a board to manage the cooperative's affairs. Cooperatives can be relatively small (like the 500+ energy cooperatives in the Netherlands), but also international organisations like Rabobank and FrieslandCampina are cooperatives.

Pro's

- Flexible in drafting of the statutes – that defines how the company is operated
- Easy to join or leave (no need to register at a notary)
- Close collaboration (can also be a con)

Con's

- All profits and losses are shared

It is possible to establish a cooperation with limited or excluded liability (i.e. BA and UA)

6.3 Foundation

A foundation is an organisation (and legal entity) whose goal is not to make a profit but instead a foundation tries to achieve a social, societal or idealistic goal. A foundation can make a profit but this profit has to be used to achieve the foundation's objective. Profit distribution to founders or directors is therefore not allowed. A foundation has a board but no members, and therefore also no shareholder nor general member meetings.

Pro's

- Limited liability
- Articles of association give flexibility in how the foundation is set up (i.e. responsibilities board members, what happens after dissolution)

Con's

- Because there are no members or shareholders and the board members normally provide for their replacement problems can arise. Therefore, the law (among other things) has provided that a director acting in violation of the articles of association can be dismissed by the court.

7. Definition scale-up plan tanktainers

Depending on the pressure required, the dimensions (40ft or 20ft) and the energy price, container prices can vary greatly. Each ship will need several containers to function optimally, because in addition to containers on board, containers will also be en route to refuelling stations and switching points. We see containers as a necessary part of the infrastructure while it is still in the build-up phase for hydrogen distribution.

Inland shipping

To determine the number of tanktainers for the 45 inland vessels, the following inputs and assumptions were considered:

- Vessel type and numbers of vessels
- Diesel consumption per year per vessel type, converted to kWh and then to H₂
- The number of days required for a round trip (trip) per vessel type
- 350 sailing days per year
- Use of 20ft tank containers with 500 kg hydrogen per tank container
- The vessel must have enough hydrogen on board for a full round trip (trip)

Table 3: Weighted average number of tanktainers required for barges

Amount ships	Diesel (l/yr)	H ₂ (kg/yr)	H ₂ (kg/day)	Days per trip	H ₂ per trip	# Tanktainers per trip
8	200.000	39.318	114	2	225	1
15	600.000	117.955	341	3,5	1.180	3
20	700.000	137.615	397	5	1.966	4
2	850.000	167.103	482	6	2.865	6
45						3,22 Weighted average

Using the inputs described above, we arrive at a weighted average of 3,22 tanktainers on the ship, per average ship for an average round trip.

As the tank containers are not continuously on the ship but also need to be refilled, several sets are therefore needed for each average set of 3,22 tank containers. As the number of tanktainers in a pool increases, fewer sets will be required per ship. In calculating the number of tanker sets per ship, we assume 2,5 in year 1 and 1,8 when all 45 ships sail. Finally, the number of ships is multiplied by the weighted average and the number of tanker sets (per year) and then rounded. This gives a total of 261 20ft tank containers for a total of 45 ships in the year 2032, and 128 tanks for 18 ships.

Table 4: Total tanktainers needed for 45 barges

	2025	2026	2027	2028	2029	2030	2031
Number of ships sailing	1	3	9	17	26	35	45
Weighted average	3,22	3,22	3,22	3,22	3,22	3,22	3,22
Tanktainer sets	2,5	2,4	2,3	2,2	2,1	2,0	1,8
Total tanktainers	9	24	67	121	176	226	261

To scale up to this number of tanks, we will also need to consider the geographical location of the routes the ships will sail.

In a next phase, a separate analyses will be required to analyse the best scale up plan, with information from shipowners, locations, H2 suppliers, logistical planning and the financial consequences.

8. Appendix A – Advantages and disadvantages H2 ownership

Table 5: Advantages & disadvantages of H2 ownership scenario's

Ownership	Advantages	Disadvantages
Tanktainer pool company contracts hydrogen on behalf of shipping companies (becomes “enabler” and owner of H2)	<ul style="list-style-type: none"> Shipping companies do not need to contract H2 from (several) H2 suppliers, also one contact for “order to cash” A full as-a-service model could be implemented Simplifying the H2 containers supply: the company will deal with multiple ship owners at the same time and will increase the H2 container stock availability and make the whole process way quicker and more efficient Not depending on one H2 supplier on one location therefore a more efficient process H2 suppliers do not need to contract with many shipping companies this lowers also the credit risk Tanktainer pool company can contract larger volumes for longer periods, probably leading to lower prices It would simplify the “left on board”/ “residue” process Could be supported by H2 certificates, Tanktainer pool company can also provide H2 certificates to shipping companies Margin will be overall low for the company as an enabler for these H2 solutions, but it can get some extra revenues as mid-streamer The mutualisation (2 businesses, customer owning majority of shares) of H2 and containers will decrease the overall working capital need (up to 15 to 30% lower, as better in terms of number of interfaces to talk to and lower safety stock) 	<ul style="list-style-type: none"> If a TC has to be founded that will own the hydrogen this will require extra funding and working capital, to pre-finance the availability of H2 H2 Tanktainer company- takes additional risks: <ul style="list-style-type: none"> Buying H2 Safety aspects in logistics H2 quality Leakage/ loss When unable to deliver etc. Requires additional staff and expertise to manage contract negotiation with H2 producers, as well as staff to manage daily supply chain operations: <ul style="list-style-type: none"> To manage quotations requests to H2 suppliers, contracting, performance management To manage planning and order to cash process for H2 materials management (can't be outsourced) between H2 suppliers, operation logistics and ships owners To manage & execute loading/unloading + transport processes – but can be outsourced to a logistics company To manage inventory If the shipping companies choose to jointly buy hydrogen, they are not solely in control. This could scare shipping companies of joining. How to prevent to be seen as a monopoly?
Tanktainer pool company performs the metering of the hydrogen in the tanks but does not become the owner, the hydrogen supplier is the owner. It administers (blockchain) how much each supplier supplied and how much was left in tank and facilitates cross- invoicing between parties	<ul style="list-style-type: none"> The tanktainer company could be smaller in size and no risk is taken because there is no ownership of the H2 which results in a cheaper tanktainer company Shipping companies can solely determine where they buy H2, they do not have to take into account other members of a buying cooperation 	<ul style="list-style-type: none"> Hard to optimize tanktainer use and filling because shipping company determines the supplier Who owns the residue Complex billing How to handle H2 prices from different suppliers/ locations? Hard to conclude contracts with H2 supplier because of smaller volumes and unpredictable demand therefore higher credit risk
H2 suppliers own the hydrogen in the tanks.	<ul style="list-style-type: none"> H2 suppliers have experience with H2 	<ul style="list-style-type: none"> Sub-optimization of the supply and logistics Ship owners still have to contract H2 from H2 suppliers, including equipment



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