Ontgassen binnenschepen streng aangepakt

Halt aan ontgassen van binnenvaartschepen

Regering wil snel een internationaal ontgassingsverbod

Ontgassen binnenschepen nog gevaarlijker dan gedacht

Ontgassen nóg riskanter

Emissies door ontgassen binnenvaart veel hoger dan gedacht

Onderzoek CE Delft: Emissie tankvaart stijgt langzamer dan vervoerd volume

Tankers ontgassen minder

Ontgassen na juni 2014 verboden

PORT OF ROTTERDAM

FEASIBILITY STUDY: SUSTAINABLE DEGASSING OF BARGES

BSC Thesis

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Colophon

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Management summary

Under the leadership of the alderman responsible for Rotterdam port affairs, and also at the request of a member of the Provincial Executive of Noord-Brabant, administrative discussions have been set up with the municipalities of Moerdijk, Strijen and Zwijndrecht. All the administrators are advocates of the introduction of a prohibition on in-transit degassing for inland navigation in 2020. However this prohibition of degassing into open air, which will be implemented in a phased sequence must be feasible to execute within the supply chain concerning the degassing of inland tank vessels.
To assess this feasibility the research question states as following:
"Is it feasible to create a sustainable and profitable solution for the degassing of barges in which an optional controlled return of chemical feedstock and chemical vapor molecules from discharged barges are brought back into the supply chain to the chemical producers necessitates."

To research the feasibility for a phased degassing prohibition, the research is divided into six research phases
Phase 1: Logistics, Barge transport and movement: In this phase an overview of the supply chain is given with an identification of the relevant product streams. The relation of these product streams are then coupled to the degassing of these products.
Phase 2: Operations and substantively aspects: In this phase an overview of the different techniques for the degassing of barges is given. When all the techniques are described, they will be assessed on criteria which give the most insight about the feasibility and use of the specific technique.
Phase 3: Active stakeholders and laws & legislation: In this phase the laws and legislation are described on an international level, national level and a local level. In addition an active stakeholder analysis and a decision tool were created which display all parties legislation within the scope of the degassing of inland tank vessels.
Phase 4: Risk setting/appointing: In this phase all the risks are appointed within the supply chain concerning degassing in the frame of a risk analysis model. Which specific risk model was used and what drives these risks was analysed. The input for this chapter are the conclusions which are drawn in the previous chapters.
Phase 5: Financial aspects and profitability: In this phase will be described which financial scenarios within supply chain designs can be developed and how these scenarios can be executed, taking into account the risks which are formulated in the previous phase.
Phase 6: Inspiring other regions and platforms: In this phase all the possible extra functions which this feasibility study can contribute and how it can inspire other regions and platforms.

The feasibility scenario which is formulated is based on the prohibition of direct degassing and is therefore a more sustainable designed supply chain scenario, which supports to implement a well working financial structure for all stakeholders within the supply chain. The key to the most feasible scenario is to intervene as little as possible within the existing supply chain. The direct impact of this in this scenario is that direct degassing is no longer possible, this creates a situation that when degassing is necessary the charterer must perform a form of controlled degassing. This makes the content of the contracts which are specified more important. The responsibility of the residual vapour in the barge must be appointed to a party in the supply chain in form of contracts and thereby the costs for degassing must be appointed based on contracts which can be handed over. In this case the responsibility and liability within the supply chain cannot be evaded through contracts. In this manner the supply chain becomes more transparent and can solve the additional costs of controlled degassing by calculating the extra costs of controlled degassing in their margins through the entire supply chain. Due to this increase of demanding price the price raises with a certain margin throughout the entire supply chain. This eventually results to a minimum increase of the margin of the final product at the end of the supply chain. Taking into account in this scenario is the re-use of the vapours, when the promising techniques with the re-use of chemicals are operational, an agreement can take place between the charterer and the shipper to make use of the recovered product. This must also be registered as transparent as possible via contracts which can be handed over. In this manner the responsibility of the vapours is registrated and it does not matter when it is traded several times within the supply chain. When the product cannot be recovered it can be controlled degassed (and destroyed) directly or the recovered product can be processed and destroyed at a waste processing plant. Through this scenario the investment/capital costs are not focused on one actor in the supply chain, this has an advantage in implementing. The degassing units are not funded by external, municipalities, overarching or additional branch parties concerning the degassing problem. An possible advantage is that this scenario will solve the degassing issue quick and as efficient as possible because everyone in the supply chain is direct financial involved in the compliance of the prohibition. This will has as consequence that the entire responsibility of product, information and financial flows of supply chain stakeholders is shared. However the overarching parties such as the Port of Rotterdam and municipalities should regulate that the amount of existing gas processing units match the required gas processing units which are in line with the estimated demand of barges which need to be degassed. By letting the costs of degassing be divided over the entire supply chain, parties will take actions to reach forms of supply chain collaboration to reduce their costs, in this manner the entire 'degassing problem' will solve itself partially.
Estimated to obtain a feasible implementation of the degassing prohibition, five degassing installations are required over six year. This has an estimated capital investment cost of € 8.525.340,- and an operational cost of € 17.272.527,- during this six years to achieve a prohibition of in-transit degassing in 2020, taking into account the formulated risks which are formulated in this study.

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I. Introduction

The Port of Rotterdam Authority develops, in partnership, the world-class European port. It has as goal to continuously improve the port of Rotterdam, to make it the most efficient, safe and sustainable port in the world. This is done by creating value for customers by developing logistical chains, networks and clusters. Thsi is done in Europe as well as in growth markets worldwide. The Port Authority is an entrepreneurial port developer, and as such the partner for world-class customers in the the petrochemical industry, energy (oil and gas), transport & logistics market segments. In this manner, the competitive position of the Netherlands as a whole and the Port of Rotterdam is strengthened. This feasibility study is executed under the flag of the division EM (environmental management). The EM department is responsible for the development and implementation of policies in the field of environment, spatial planning and sustainable development. Within the domain of EM are all the activities which are focused on the ability to achieve future growth of the port of Rotterdam, including related transport flows, coupled to an improvement in the quality of the environment. This is translated into the following main tasks:

- To ensure an efficient and systematic management of the environmental space of the Rotterdam port area;
- Developing the Global Hub and Europe's Industrial Cluster as a leader in the field of sustainability;
- Environmental consultancy for optimal integration of customers and activities in the port of Rotterdam and flexible licensing and planning procedures.

Degassing is the venting of residual vapours from the hold of a ship. During the transport of the organic substances, VOC's[1] are emitted to the atmosphere. The liquid cargo residues must first be evaporated before they can be degassed. This happened by ventilating these vapours directly into the open air. Degassing mainly takes place when changing cargo. By degassing the ship's hold, the vapour from the previous cargo is removed. The amount of degassing, and thus the emission of VOCs, can be reduced through dedicated or compatibility shipping[2]. However, to achieve an efficient operational management of inland navigation, using only dedicated/compatibility shipping is impossible. The need for degassing of inland tank vessels will remain to exist for incompatible cargoes and when the vessel is going to the shipyard.

No emission-limiting measures are taken and the vapours are therefore freely emitted to the atmosphere. With the exception of a few highly toxic substances and petrol, in-transit degassing of substances is permitted. However, the in-transit degassing of volatile organic compounds on inland waterways leads to obnoxious smells and a potential health risk. The licensing of companies for benzene emissions even entails a minimisation duty. Extremely strict emissions regulations are applied. A large discrepancy has arisen between the approaches for companies on land and ships. The transport of various compounds jointly lead to significant concentrations of VOC emissions at a regional level as a result of degassing.

The topic of degassing inland tank vessel (barges) has been on the political and administrative agenda in the Rotterdam region since 2009. Several consultative bodies have arisen and studies have been started in this period, which are in an ongoing process. This study is in scope of the degassing of inland tank barges. The consultative bodies, alternative gas processing techniques and the ambitions of stakeholders are examined in this study. It is likely that, in time, a separate procedure will be started up for seagoing ships.

[1] Volatile Organic Compounds

[2] If a ship transports the same type of cargo after sequential after each other or a substance which can be loaded on top over the previous substance, it is called dedicated transport or compatibility shipping.

The research question in this feasibility study results of the above stated problems. The research question states as following:

"Is it feasible to create a sustainable and profitable solution for the degassing of barges in which an optional controlled return of chemical feedstock and chemical vapor molecules from discharged barges are brought back into the supply chain to the chemical producers necessitates."

The objectives which will be achieved by answering the research question during this project are:

- Defining the feasibility for the implementation of a new scheme enabling the controlled recovery of molecules from degassed barges;
- Describing the risks which occur within the project and the degassing of barges;
- Describing a roadmap to establish a demonstration project in the area of Rotterdam;
- Inspiring other regions for implementing a scheme focused on smart logistics: optimal recovery of chemical molecules within the supply chain without further congestion at jetties.

The feasibility study reporting is structured and divided in four chapters which are:

I. **Introduction**
The introductions forms the background information of this study, how it is build up in form of reporting and it contains the main research question and objectives.

II. **Research**
This chapter holds the complete mindset of the research, the research manner will be In clarified and which sources, literature and expert judgments are consulted. This chapter also divides the feasibility study into six phases which will be described in the research chapter.

III. **Feasibility aspects**
This chapter contains the researched content and findings, these are structured in the six research phases which are created and described in depth in the chapter research.

IV. **Conclusions**
The sub-conclusions and findings are summarized into a major conclusion which will form the base of the recommendations towards the feasibility of the phased direct degassing prohibition.

The phased degassing prohibition is researched is in six phases in the chapter feasibility aspects. These phases have a strong cohesion with each other on different levels and in different relationships to each other. These phases are:

II. Research

1. Research ground plan

1.1 Research introduction

The complete mindset of the research and the research manner will be In clarified in this paragrapgh. This will be done by detailed background information about the research and the inducement of the study.

1.1.1 Research inducement

Under the leadership of the alderman responsible for Rotterdam port affairs, and also at the request of a member of the Provincial Executive of Noord-Brabant, administrative discussions have been set up with the municipalities of Moerdijk, Strijen and Zwijndrecht. All the administrators are advocates of the introduction of a prohibition on in-transit degassing for inland navigation as quickly as possible. Taking these developments into account as well as asked question in the city council of Rotterdam but also in the Dutch parliament Deltalinqs and the Port Authority of Rotterdam have drafted conditions for a Memorandum of Agreement in order to, in a controlled process reduce the vapour emissions of various products. By means of the Memorandum of Agreement focussed on the reduction of Benzene and Benzene like substances the industry is able to get a firmer grip on the coordination in this discussion and can indicate what is possible and what is not possible, sates (Deltalinqs & Port of Rotterdam Authority, 2014). This feasibility study will support the Memorandum of Agreement and will help to gain more insight in a possible phased degassing prohibition. The phased degassing prohibition can be defined in the phased prohibition of substances, specified in UN-codes, this is an indication of how the degassing prohibition will be rolled out, which is displayed in figure 1 below.

Phased prohibition indication	Un-Code
Active prohibition: gasoline (gasoline directive)	UN1203
Prohibited from 2015: Benzene	UN1114
Prohibited from 2016: Substances containing >10% benzene	UN1267, UN1268, UN1863, UN1993, UN3295
Prohibited from 2017: top 10 priority substances (CE Delft)	UN1090, UN1145, UN1230, UN1280, UN2398
Prohibited from 2018: Smelling/nuisance substances (PoR)	UN1917, UN1198, UN2209, UN2527, UN2045, UN1221, UN1919, UN2348, UN1129, UN1280, UN2055, UN1299
Prohibited from 2019: Top 25 priority substances (Cefic)	UN1170, UN1175,UN 1216, UN1223, UN1307, UN2789, UN3082, UN3257, UN9001, UN9003
Prohibited from 2020: All remaining (VOC) substances	Rest

Figure 1: The phased prohibition of the degassing of inland tank vessels specified in UN-codes

1.1.2 Background information

One of the ambitions identified in the port areas of Amsterdam, Rotterdam and Antwerp (the ARA area) is focusing on the reduction of the residual concentrations of Volatile organic compound (VOC) in the air and to enhance the resource efficiency within the supply chain between producer and user of chemicals for specific products: UN 1114 (benzene), UN 1268 (naphta and petroleum destillates) and UN 3295 (Liquified hydrocarbons). The accompanying percentage per UN-code is displayed in figure 2. A controlled return of chemical feedstock and chemical vapor molecules from discharged barges in the ARA area is one of the solutions to achieve this ambition. By optimizing the management of handling of volatile molecules throughout the supply chain, several positive results will be achieved:

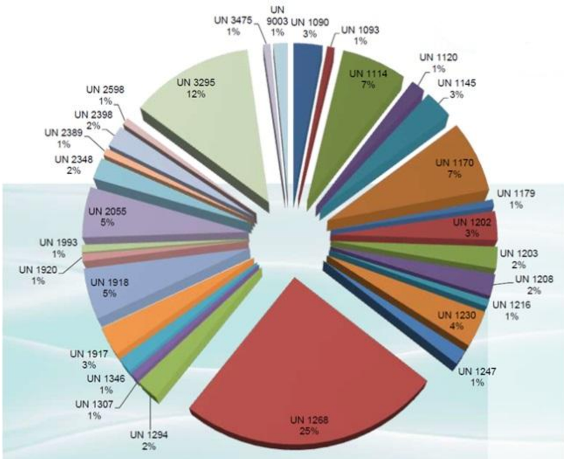

Figure 2: Barge degassing percentage per UN-code| Source: EBU (Lurkin, 2013)

- A re-use of chemicals will be optimized,
- A value destruction of products and raw materials will be reduced to a minimum;
- A congestion at the jetties due to controlled degassing will be avoided;

An additional problem of this feasibility research lies in the lack of a controlled return of chemical feedstock and chemical vapor molecules from discharged barges to the chemical producers necessitates. For benzene products and benzene containing products a prohibition for degassing while sailing will be active on short-term.

An important criterion in the selection for degassing techniques was the required plot space for the techniques since they must be suitable for floating or on board application. Also the suitability to be used in a closed loop (recycle of treated vapors back to the ship or the producer of products (chemicals or minerals)) was an important criterion. A demonstration pilot project with participation of the relevant industries in the supply chain in the Port of Rotterdam is needed to enhance smart logistics in Europe. The demonstration pilot project will prove the feasibility of a sustainable solution for the degassing of barges with optimal recovery of volatile organic compounds within the supply chain between producer and user without congestion at jetties.

1.2 Project Build-up

1.2.1 Build-up introduction

In order to conduct the research as synoptically as possible, the research is divided into six research phases. The research question consists of subsidiary question which are divided into these six research phases. The research and subsidiary questions will ultimately lead to achieved objectives which are stated in this paragraph.

1.2.2 Research question

The research question states as following:

"Is it feasible to create a sustainable and profitable solution for the degassing of barges in which an optional controlled return of chemical feedstock and chemical vapor molecules from discharged barges are brought back into the supply chain to the chemical producers necessitates."

1.2.3 Subsidiary questions

The research question can be further specified into six phases with accompanying subsidiary questions of the project, which are displayed below in figure 3.

Phase 1: Logistics, Barge transport and movement

- How is the transport/barge movement of chemical feedstock organised within supply chain, divided in fixed sailing routes and UN-code specific.

Phase 2: Operations and substantively aspects

- Which options are available for the degassing of barges and which option(s) are the 'best' for the degassing of barges, based on set criteria.

Phase 3: Active stakeholders and laws & legislation

- Which stakeholders, laws and legislation have a role in executing this feasibility study and on which manner do they affect this feasibility study.

Phase 4: Risk setting/appointing

- Which risks are a major risks within the prohibition of degassing barges and for which parties are these risks applicable.

Phase 5: Financial aspects and profitability

- Which financial scenarios can be developed and how can these scenarios be executed.

Phase 6: Inspiring other regions and platforms

- How can this model be used for others substitutes and potential stakeholders

Figure 3: Phased subsidairy questions

1.2.4 Objectives

Several objectives will be achieved during this project, namely:

- Defining the feasibility for the implementation of a new scheme enabling the controlled recovery of molecules from degassed barges;
- Describing the risks which occur within the project and the degassing of barges;
- Describing a roadmap to establish a demonstration project in the area of Rotterdam;
- Inspiring other regions for implementing a scheme focused on smart logistics: optimal recovery of chemical molecules within the supply chain between producer and user of chemicals without further congestion at jetties.

1.3 Research design

1.3.1 Theoretical framework and research plan

Different research methods where used within this research. An overview of the research methods are stated below and are further specified why these specific research methods where chosen. These methods will form a theoretical framework which states how this research is grounded.
Case studies where used within this research on an individual basis as well as a comparative basis. The outcomes of various case studies where used developing this feasibility study. The case studies where executed for the use of mapping the volumes and product flows within the supply chain, creating an overview of the degassing techniques and gain insight about the current state of the supply chain concerning the degassing of inland vessels. Within the case studies qualitative data research and research models have been used for optimal interpretation of the given data. The techniques, tools, and case studies which have been used can be found in figure 5, specified in the accompanying applicable subsidiary phase and research method.
The survey during this research was executed in the form of interviews on a qualitative basis on a detailed level. Within this survey research there was chosen for an approach to interview relatively small numbers of experts, which represent all the stakeholders within the supply chain. The gain of this method is the guaranteed level of representativity and specificity of the survey. All the held interviews were specified into interview groups, this is done for the purpose of better alignment within the subsidiary phases. The interview groups are displayed below in figure 4.

Interview groups	Group 1	Group 2	Group 3	Group 4
collective name	**Refineries**	**Barge owners**	**Gas processing parties**	**Overarching/external expertise parties**
Specific parties	Exxon Mobil Lyondell Shell	Barge traders Individual barge owners Interstream Barging Unitas/GEFO	APM terminal AQ Linde Desotec Ipco Power LTT Mariflex Vaporsol SIHI	Cefic DCMR Deltalinqs EBU ISPT Municipalities (local, national and international legislation) Port of Rotterdam (internal) Rijkswaterstaat RoyalHoskoningDHV VNCI VNPI VOTOB

Figure 4: interview groups

Field research was used by the means of the additional documentations which are obtained by observations and measurements which are done during the research by the different gas processing parties. The attending of meetings and the cooperating in coherent projects to gain key insights and knowledge about the dynamics of degassing of inland vessels are an important part of the field research which is done.
Desk research was used in various ways accompanying this research which are, but not limited to the use of:

- Additional literature to support the research models which were used;
- Existing materials and sources which have no direct link/contact with the research object;
- The knowledge of external experts resulting in meta-analysis of secondary data.

Modelling is used in the research through systematic models, which are used to gain insight in the mechanisms of the supply chain concerning the degassing of inland vessels and to make an analysis of a possible future situation. Modelling is also used in the creation of deliberation and decision models. This is done by specific research models which are further specified in figure 5.

The use of benchmarking research was applicable when comparing the processes, performance metrics and industry best practices of gas processing units. Benchmarking was also used to compare the feasibility study scoped on the ARA-area to other regions For this benchmark sufficient data is necessary and obtained via other previously stated research methods.

1.3.2 Methods, techniques and tools

The methods of the theoretical framework and research plan are further specified in the figure below.

Subsidiary phase	Research method	Techniques/Tools	Sources
Phase 1	• Comparative case study • Survey • Qualitative data research • Desk research	The outcomes of two major case studies concerning degassing of barges will be hierarchical compared. Active parties which are responsible for barge movement within the supply chain will be interviewed. The variation in product flows specified per Un-code will be obtained. Secondary literature which give additional insights will be consulted.	**Interviews:** • Group 1 & 2 **Literature/case studies:** • Update estimate emissions degassing inland tank vessels, CE Delft • Praktijk onderzoek 'Ontgassen binnenvaart', Antea Group • Logistics Management and Strategy, A. Harrison & R. Van Hoek
Phase 2	• Individual Case study • Qualitative data research • Modelling • Benchmarking • Field research	The outcomes of a case study concerning reviews of techniques for the degassing of barges will be consulted. Active parties which are involved with the degassing of barges within the supply chain will be interviewed in depth. Secondary literature which give additional insights will be consulted. All the results of technical possibilities will be benchmarked in a SWOT-analysis.	**Interviews:** • Group 3 & 4 **Models:** • SWOT-analysis • Balanced scorecard **Literature/case studies:** • Review of techniques for degassing barges, Royal Haskoning DHV • Shell Report appendices, Shell • Degassing of chemical barges: Assessment of on-board degassing and treatment of the purge gasses, MTSA Report
Phase 3	• Individual Case study • Survey • Desk research • Modelling • Field research	The findings of the first two phases will form a basis where the law and legislation will be taken into account in the third phase, this will be displayed in a separate perspective for each stakeholder within the supply chain. This is done by a stakeholder-analysis which additional requires interviews. An overview of the laws and legislation will also be from a supply chain point of view in from of a decision making tool.	**Interviews:** • Group 4 **Models:** • Stakeholder-analysis • Decision making tool **Literature/case studies:** • Degassing memorandum of agreement • ADN • Havenbeheersverordening
Phase 4	• Literature analysis • Individual Case study • Field research • Desk research	In this phase all the active parties within the supply chain will divided into groups and for each group risks will visualised concerning the feasibility of a potential upcoming degassing prohibition for barges, this is done with a risk visual analysis. Secondary literature which give additional insights will be consulted. All gained experiences and insights obtained and held interviews during this feasibility study will be used in this phase.	**Interviews:** • Group 1, 2,3 and 4 **Models:** • Risk visual analysis **Literature/case studies:** • Logistics & Supply Chain Management, M. Christopher • Business Logistics: Supply Chain Management, R.H. Ballou • Additional risk setting/appointing literature
Phase 5	• Literature analysis • Survey • Field research • Desk research	When a complete clarification of dynamics and problems in the supply chain of the degassing of barges is created in the previous phases, it will be linked with a financial analysis to assess the feasibility. Various financial structures will be created within the supply chain. When this is done the feasibility study can be concluded.	**Interviews:** • Group 1, 2,3 and 4 **Literature/case studies:** • Financial literature • Bipro degassing Presentation • Outcomes of the previous research phases
Phase 6	• Qualitative analysis • Benchmarking • Desk research	When the feasibility study is concluded, it can perform as an example to inspire other regions with comparable sustainable solutions. This is done by benchmarking the outcomes of the feasibility study with other regions and sustainable solutions. Secondary literature which give additional insights will be consulted	**Literature/case studies:** • Feasibility study 'Sustainable degassing of barges'

Figure 5: Research methods, techniques and tools in subsidiary phases displayed.

1.3.3 Execution and conditions

The way the research is planned alters will form the end result. This is why the research approach is the base of the research and forms a general guideline through the whole process. The schematic display of the research approach is shown in figure 6 below.

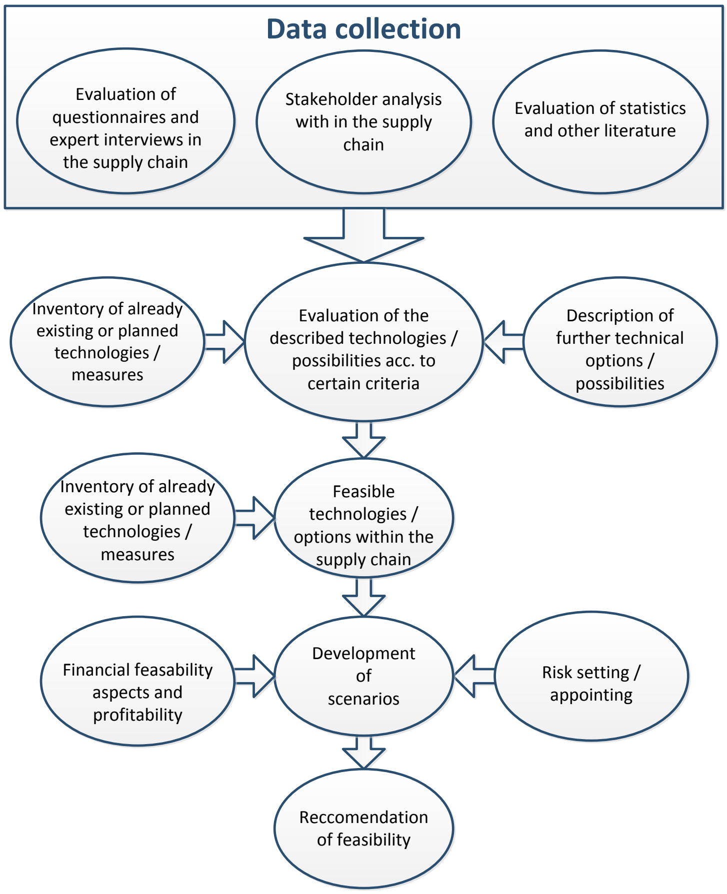

Figure 6: research approach

1.3.4 Cohesion with other projects

This feasibility has a strong cohesion with other projects, the content of these projects and the cohesion with this feasibility study are described in figure 7 below.

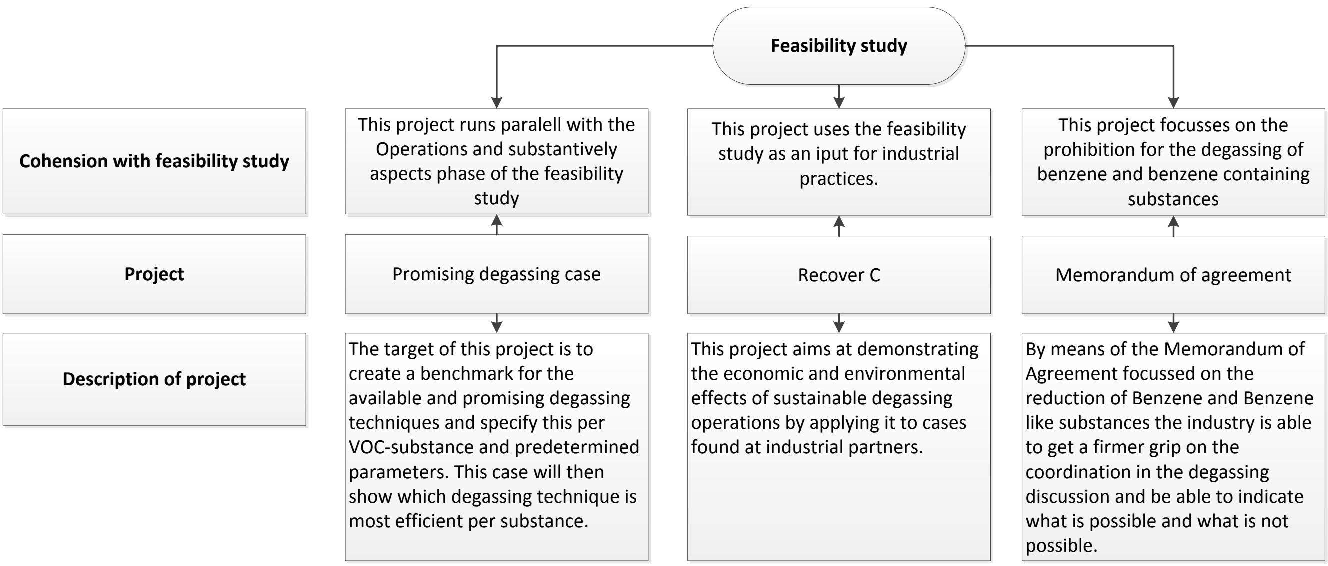

Figure 7: Cohesion with other projects

III. Feasibility aspects

2. Logistics, Barge transport and flow of product streams

2.1 Introduction

In this chapter an overview with of the supply chain is given with an identification of the relevant product stream. The relation of these product streams are then coupled to the degassing of these products. The underlying reasons and dynamics within this supply chain are exhibited. This will eventually contribute to a clear futuristic need of degassing to adhere the prohibition of direct degassing.

2.2 Identification of current relevant product streams

An analysis is done which gives a clear identification of the relevant products streams. The analysis which is done is based on the database of IVS'90 used in the 'Update estimate emissions degassing inland tank vessels' executed by (CE Delft, 2013). This database is managed by the service of: 'Water, verkeer en leefomgeving' of Rijkswaterstaat. The database contains all transports of chemicals and petroleum products by inland transport. As ship owners are legally obliged to report these transports, it can therefore be assumed that the file is a complete reflection of what is being transported. Forty-one product streams where analysed for this study. This relates to the 25 products with the highest throughput, to which a series of specific products are added which are relevant from a specific environmental point of view.

The calculation of the total amount of degassing barges is done by comparing the number of shipping movements within the Netherlands with the total transported weight in tons in the Netherlands. The transported weight is divided in the amount unloaded tons in the Netherlands and amount of unloaded tons outside the Netherlands. The amount of unloaded tons in the Netherlands is then divided in the amount of unloaded tons in the port of Rotterdam and the amount of unloaded tons in the Netherlands excluding the port of Rotterdam, this can be defined as the Port of Amsterdam, Sealand Port and the Port of Moerdijk. The product streams can then be identified on the basis of the unloaded tons per product for each destination and total barge movements for each product, these values can be found in appendix 1. The product streams combined with the total barge movements for each product can be divided into vessels which are degassing or not degassing, this is dependable on the next load. Some products are transported dedicated, this can be a reason to not degas directly into open air. Another possibility is when the next load is compatible with the previous load, in this case there might also be no need for degassing. The occurrence ratio between these actions for each product specified are displayed in appendix 2. With the assumed degassing percentage for each product and the calculated product flow an amount of the degassing barges for each barge movement can be determined. The amounts of the degassing of barges for each product specified, as summarised displayed in figure 8 can be found in appendix 3.

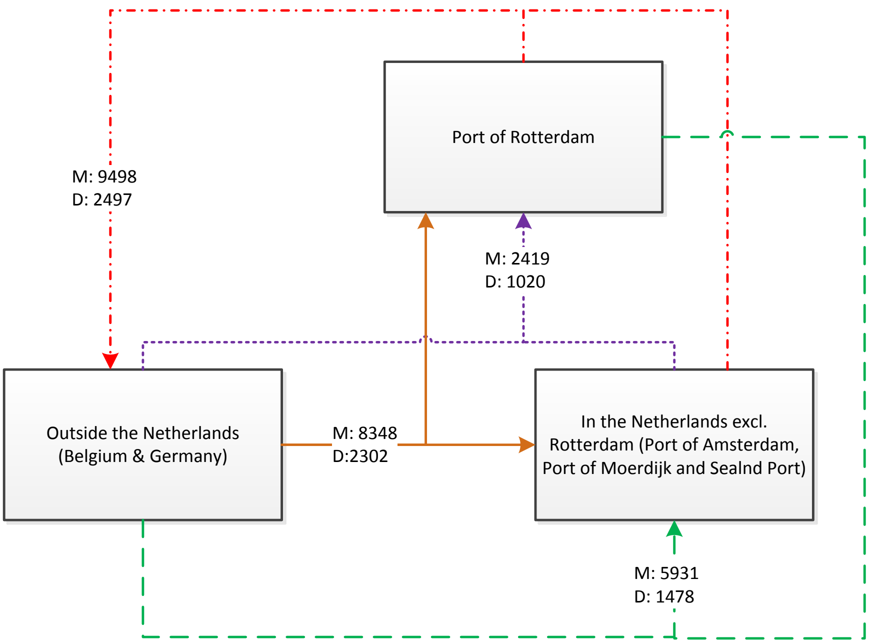

Figure 8: Barge movement (M) in comparison with direct degassing of barges (D)

2.3 Identification of supply chain

It is of great importance to fully understand the supply chain concerning the degassing of barges with its roles and responsibilities. The refineries processed the (chemical) feedstock. At this point it is stored at the filler in large storage tanks. This is In contract of a trader which can profit from rapid fluctuations in price through buying and selling on a trading platform. Another business of a trader is blending, this is mixing the products with additives if conform the demands of the receiver. After these steps the chartered barges are freighted. This is done by expeditors, the business of these trades is to fill the hold of the chartered barges or owned fleet as efficiently as possible. Barges are chartered for the transport to the final receiver which further, processes or uses the product. This overview is schematic displayed in figure 9.

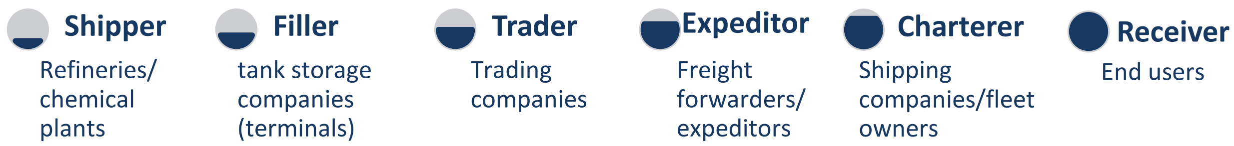

Figure 9: Supply chain concerning the degassing of barges

Contracts within the supply chain are in different sorts. The shipper holds a contract with the receiver, this contract contains a specific loading quantity, date of delivery and quality agreements for the relevant load. The shipper also has a contract with the expeditor, which charters the barge as efficiently as possible and makes sure the barge is at the receiver at the agreed time and under the agreed conditions. The shipper could have an contract with a filler, which stores the relevant load, the charterer with its barge must then load the cargo form the filler in his barge and deliver at the load at the receiver. This creates a bond in form of a contract between shipper, fillers and charterers. Traders trade the product during this process to gain profit form increasing margins on products . this can be traded during the physical transport of the loads, due to this trading activities the ownership of the load is in some cases unclear.

2.4 Motive for the degassing of barges

To gain more insight in the dynamics of the degassing problem and reduce the amount of direct degassing it is vital to understand the underlying reason for the degassing of barges.
The EBU (Lurkin, 2013) performed a survey among its members of what the main reasons are for the degassing of barges and which substances are degassed more often than others. The outcomes of this survey represent +/- 5% of the inland tanker fleet (B, CH, D, NL). The products which are degassed most times are UN 1268, 3295, 1114 and 1170. The outcomes stated that there where different reasons for degassing into open air, not one main reason.
The reasons stated in the in the survey were as following:

- The installation on the land side does not have a vapour recovery sytem (32,5 %)
- Quality requirements (28,0 %)
- As precaution; in this case another product could be charged (22,0 %)
- The vapour treatment system (e.g. incinerator) could not treat the vapours (9,5 %)
- Safety requirements (4,6 %)
- Other (e.g. shipyard, cleaning tanks etc.) (3,4 %)

The interesting dynamics in these outcomes are in line with input from interviews with the shipping companies which were conducted for this study. The most common reason for direct degassing from a charterer's perspective is the lack of a vapour recovery systems on the land side which can be used. This is related to the high jetty occupation of terminals. Mostly terminals use their VRU-systems for their own processes (dedicated use). An overview of the available locations for degassing in the ARA-area are displayed in figure 10 .
The second most common outcome, quality requirements is related to the third most common outcome, the precaution of another product which could be charged. Besides certain product quality demands, Oil majors/terminals demand inert vessels, this is an extra demand that has to be taking into account for the shipping owners/fleet owners. For instance a terminal which has a VRU might not accept a the vapours of an non-inert ship because their storage tank is inert or vice versa. Because of these quality requirements and the

uncertainty of the knowledge of a next possible load, the market for charterers becomes more competitive and barge owners tend to be as flexible as possible. This has as consequence that the barge owner will degas as soon as possible to not be obstructed by these demands. In cases there might be a compatible load as next load and the degassing of the barge is unnecessary. A reason for these 'unnecessary' direct degassing of barges might be a lack of visibility of the barge owners and fleet owners. If a prohibition of the direct degassing of a substances is active it will cost money to degas. Which is accounted to the charterer and which will be passed to the contractor or receiver. These costs have a negative impact on the entire supply chain, this is prognosed to lead to a more effective deployment of barges within the barge fleet of an owner. This could also be solved by a form of supply chain cooperation.

	Location	Provider	Technique	operational status
The Netherlands				
	Moerdijk	ATM Terminal	Incineration and washing	Operational
	Rotterdam	Rubis Terminal	Incineration and VRU	Operational
	Vlaardingen	Mariflex	Cryo-condensation	Testing
Belgium				
	Antwerp	MTD Terminal	Adsorption	Operational
Germany				
	Wesel	Sappi Logistics GmbH	Washing	Unknown
Mobile units				
	Antwerp	AQ Linde	Cryo-condensation	Testing
	Amsterdam	Ventoclean	Condensation	Testing
	Amsterdam, Antwerp, Duisburg	Vaporsol	Adsorption	Testing

Figure10: Available degassing techniques in the ARA-area and Germany

2.5 Futuristic degassing needs

As earlier mentioned the prohibition of the degassing of barges is a phased project. The prohibition is phased in an order of UN codes which are displayed and specified in figure 1 in the introduction. Two extra phases are recommended to create a more controlled and better phased prohibition. These extra phases are specified as the 'top 25 priority substances' composed by Cefic (Van de Broeck, 2013) and the 'list of smelling/nuisance substances' (PoR Harbour regulations, 2010) which are assumed to be phased prohibited in 2019 and 2018. These additional stages in the phased prohibition, respectively a decrease of 27% of the direct degassing of barges, which represents 13% of the total barge movements for the specific UN-codes. The prognosed effects of the degassing prohibition translated into the amount of direct degassing of barges and total barge movement are displayed in figure 11 and a graphic overview is displayed figure 12.

Phased prohibition	Specification	Prognosed decrease in degassing (%)	Percentage of total barge movements
Active prohibition	gasoline	100%	81%
Prohibited from 2015	Benzene	91%	76%
Prohibited from 2016	Substances containing >10% benzene	54%	38%
Prohibited from 2017	Top 10 priority substances (CE Delft)	39%	21%
Prohibited from 2018	Smelling/nuisance substances	35%	16%
Prohibited from 2019	Top 25 priority substances (Cefic)	15%	6%
Prohibited from 2020	All remaining (VOC) substances	0%	0%

Figure 11: Effects of the degassing prohibition in the amount of degassing barges and total barge movement

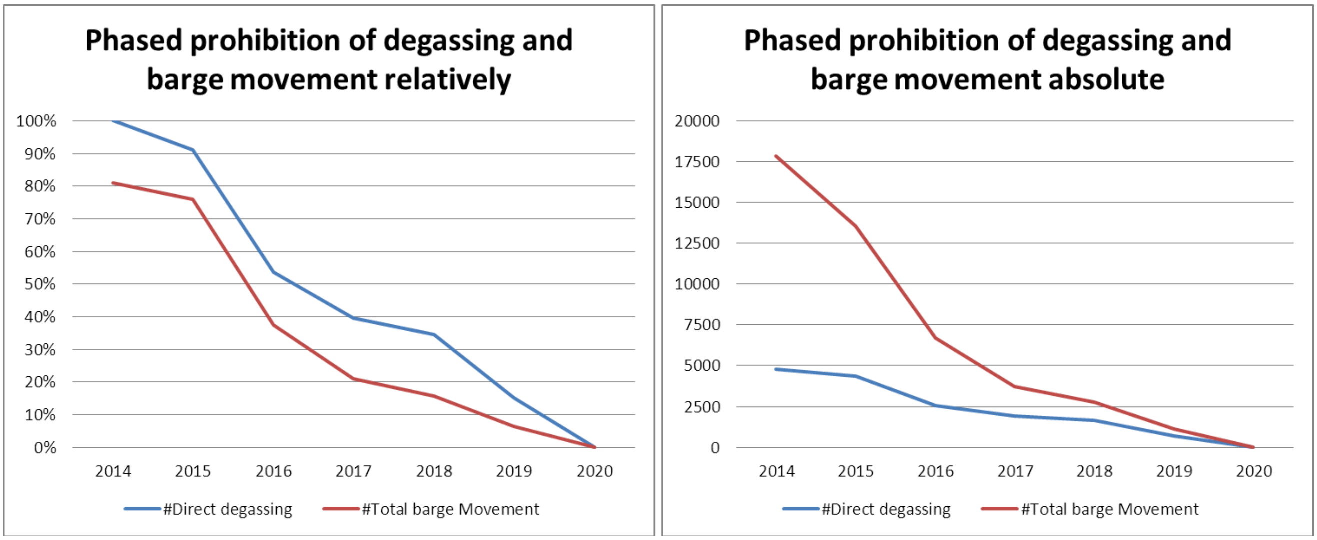

Figure 12: Effects of the degassing prohibition in the amount of degassing barges and total barge movement relatively and absolute

2.6 Conclusions phase 1

All the major conclusions remarked in the logistics, Barge transport and flow of product streams Concerning the degassing of barges are stated in this paragraph.

- The most common reason for direct degassing from a charterer's perspective is the lack of a vapour recovery systems on the land side which can be used. This is related to the high jetty occupation of terminals. Mostly terminals use their VRU-systems for their own processes (dedicated use).
- The directing role of the supply chain is in the hands of the shippers and expeditors. The barge/fleet owners are in a reactive role in this situation this is creates a lack of insight.
- Because of quality requirements and the uncertainty of the knowledge of a next possible load, the market for charterers becomes more competitive and barge owners tend to be as flexible as possible. This has as consequence that the barge owner will degas as soon as possible to not be obstructed by these demands. In cases there might be a compatible load as next load and the degassing of the barge is unnecessary.
- In some cases the load of barges continuously switches of owner within the supply chain. The reason for this is because the product can be traded several times when moving through the supply chain. Due to this changing ownership of freight within the supply chain, it is unclear which actor is eventually responsible for the residual after unloading the product. Due to this lack of responsibility it is in most cases that the party which is at the end of the physical flow of products becomes responsible. This makes the barge owner responsible for the degassing of barges and makes them responsible for the corresponding costs and loss of time.
- The prohibition of the degassing of barges must be executed within a period of seven years (2014 – 2020). It is key that the phased prohibition is performed as gradually as possible divided over these seven years.
- When a barge (owner) is chartered for a certain transport and charges an all-in tariff per hour for the transport which is executed. The time estimated for degassing of the barge is taking into account and added up with the total required transport time, which will form together the total charged time. This will create a lower threshold for direct degassing, because in this manner direct degassing has no direct effect on the cost effectiveness and is not considered as 'lost' time. In some cases barges will even take a detour for the purpose of degassing.

3. Operations and substantively aspects

3.1 Introduction

In this chapter an overview of the different techniques for the degassing of barges is given. When all the techniques are described, they will be assessed on criteria which give the most insight about the feasibility and use of the specific technique. The outcomes of these assessment will be compared. Then external factors which occur will be taken into account which will form a SWOT-analysis from which vital conclusions and developments can be subtracted. All the assessed techniques are stated and divided in divisions, as displayed in figure 13.

Conventional treatment:	Logistic solutions:	Recovery:	Destruction:
Direct degassing (moored)	Dedicated transport	Scrubber	(catylic-) oxidation
Direct degassing (sailing)	Load on top	(membrane) filtration	Ionisation
Vapour balancing		(Cryo-) condensation AQ Linde	Biological treatment
Vapour recovery systems		(Cryo-) condensation Mariflex/purgit	Incineration
Washing		Condensation STS Ventoclean	
		Adsorption	
		Micro gas wash Vaporsol	

Figure 13: Division in degassing techniques

3.2 Degassing techniques exploration

3.2.1 Micro gas wash: Vaporsol

The mist scrubbing technique, developed by Micro gas wash and tailored for degassing by Vaporsol. The technique is a solution for the controlled degassing of barges. The principle of the technique is to guide the vapours through a relative small bed of active carbon to adsorb various pollutants and subsequently through a mist of fine droplets containing water with an additive (detergent). Both polar (soluble in water) and non-polar chemicals can be removed from the vapours. The mixture of water, detergent and VOC´s are washed in a small mist scrubber where the liquid VOC´s are removed and collected in a residual IBC. After this gas washing the remaining vapours are guided through a larger activated carbon bed to remove the remaining pollutants. The remaining residue is a mix of water, VOC substance and detergent. The detergent is biodegradable, in this manner the chemicals can possibly re-used. (Royal HaskoningDHV, 2013). A schematic overview of the Vaporsol technique is displayed in appendix 4, obtained form (Vaporsol, 2013).

3.2.2 Condensation: VentoClean-System

The VentoClean-System is a closed loop system which is developed for the degassing and cleaning of barges, tanks and piping. The VentoClean technique is based on the principle of condensation. The vapour residue in the barge tank(s) are ventilated into the VentoClean –System. Subsequently the vapours are cooled with a conventional cooling method. Due to the rapid decrease of temperature, the vapours will condensate (become liquid). The liquid VOC substances are captured in an external storage tank and can be reused. The remaining vapours are heated again and ventilated back into the barge. Optionally gaseous nitrogen can be added to the vapours before these are ventilated beck into the barge because a nitrogen separator is also installed inside the VentoClean skid unit. When nitrogen is added the barge becomes inert during the process. (J. Kuijpers Wentink, 2013). A schematic overview of the VentoClean-System technique is displayed in appendix 5.

3.2.3 Cryo-condensation: AQ Linde

The Cryo-condensation unit of AQ Linde is a system intended for the degassing of barges. The principle of this technique is based on liquid nitrogen which is used as a cryogen in cryo condensation. The loaded exhaust air is super-cooled in heat exchangers to such a degree that the pollutants or valuable resources that it contains can condense or freezes out if the temperature is dropped below the condensation point. The necessary condensation temperature is defined according to the composition and the required purity of the vapours. In individual cases, temperatures below –150 °C may be necessary. Depending on requirements, the residual cold in the pure gas and the gaseous nitrogen can be used to pre-cool the gas flow. The nitrogen used can be further used by feeding it into a nitrogen network. During the first phase of degassing the maximum capacity will not be realized. Due to the high VOC concentrations the capacity is limited to realize a sufficiently high VOC removal rate (Royal HaskoningDHV, 2013). A schematic overview of the Cryo-condensation technique of AQ Linde is displayed in appendix 6.

3.2.4 Membrane filtration

Membrane filtration is based on separation of VOC's from a mixture of VOC-vapours and air or inert gas by a semi-permeable membrane. This membrane has a larger affinity for VOC's than for air. The VOC's are passing through the membrane preferably. Thereby the raw vapours are divided into a VOC-lean and a VOC rich stream. The VOC-lean stream, referred to as "retentate", is vented to atmosphere or to a polishing unit. The VOC-rich stream, referred to as "permeate", is fed to the raw gas upstream of the compressor. The driving force for separation of VOC's from the original vapour stream is the concentration level in the raw vapour stream and the pressure ratio over the membrane. Membrane filtration techniques can be applied in three configurations (Shell Report appendices, 2012). A schematic overview of a typical membrane filtration techniques is displayed in appendix 7.

3.2.5 Adsorption: (Regenerative) pressure swing adsporption

In a Pressure Swing Adsorption unit volatile organic components (VOC's) are removed from a vapour stream by adsorption on activated carbon. After loading the adsorbed VOC's are removed by evaporation under vacuum from the activated carbon. Normally a PSA-unit consists of two parallel beds of activated carbon. While one bed is loaded with VOC's the other bed is regenerated. The transport of the vapour flow through the unit is accomplished by displacement of vapours due to filling vessels with liquid. Alternatively a suction blower, which therefore operates in a clean and normally safe environment, can be applied. In order to regenerate a carbon-bed a vacuum-pump is applied. The evaporated VOC's are either absorbed in a flow of a stored product or condensed in a heat exchanger. The cycle-time for absorption/regeneration in case of recovery of concentrated VOC-vapours is typically 10 - 15 minutes. Regeneration starts immediately after the adsorption cycle. Change-over from adsorption-mode to regeneration-mode is controlled either by temperature-indication, concentration measurement or a preset timer. During regeneration a minimal flow through the carbon bed is necessary in order to remove the evaporated VOC's. Therefore a part of the effluent of the carbon-bed in adsorption-mode is directed to the carbon-bed in regeneration-mode (Shell Report appendices, 2012). A typical flow-scheme of a pressure swing adsorption unit is presented in appendix 8.

3.2.6 Adsorption: Activated carbon adsorption with sacrificial filter beds

Activated carbon adsorption is also applied in a non-regenerative mode, where the activated carbon is supplied in cartridge filters that are saturated during degassing operation. When the activated carbon is saturated the cartridges are replaced by the supplier of the activated carbon. It is good practice to install two activated carbon filters in series with an analyzer after the first filter to detect saturation of the first filter. This type of system can only be applied to low vapour concentrations. In cases where high solvent concentrations are expected, the adsorption heat can lead to dangerous situations and precautions should be taken (e.g. a Nitrogen flushing system shall be installed) (Royal HaskoningDHV, 2013). A typical flow-scheme is presented in appendix 9.

3.2.7 Incineration

By incineration of organic vapours the exhaust gas from the combustion chamber has a high temperature. In order to reduce the requirement for auxiliary fuel the heat from the combustion gases can be recovered by pre-heating the combustion air (primary air) and/or the waste gas. With heat recovery a thermal efficiency of 70 - 75 % is feasible and auto thermal operation is possible at VOC-concentrations of 6 – 10 g/Nm3. Simplified schemes of these configurations are presented in appendix 7. In this guideline the configuration with no heat recovery is considered a "base-case", because design and investments for heat-exchangers are strongly depending on the specific requirements of the client. Also investments for heat-exchangers are high and may result in a total investment for an incinerator-unit that is not competitive to other vapour treatment techniques (Royal HaskoningDHV, 2013). A flow-scheme of the working of three types of incinerators are presented in appendix 10.

3.2.8 Scrubbing

Wet scrubbing (or absorption) is a mass transfer process between a soluble gas and a solvent in contact with each other. Physical scrubbing is preferred for chemicals recovery, whereas chemical scrubbing is restricted to removing and abating gaseous compounds. Physicochemical scrubbing takes an intermediate position. The component is dissolved in the absorbing liquid and involved in a chemical reaction. An optimum design of scrubbing systems to achieve low exit concentrations includes high reliability, automatic operation and counter-current flow of liquid and gas. There are many different designs for scrubbers, but a very common example of a packed bed scrubber is presented in appendix 11 (Robles, 2012).

3.2.9 Ionisation: Ion2Air Liquid Transfer Technology

The technique is based on the principle that oxygen ion molecule´s potential is greater than other VOC substance´s potential energy. Due the difference in potential energy, as oxygen ion molecule breaks down carbon and hydrogen then forms carbon dioxide (CO_2) and water (H_2O) molecules. The dimensions of the Ion2Air unit are two 20'ft containers, of which 1 container has the function of acting as a gas-mix chamber, the other container has the function of housing the ionisation techniques. A schematic overview of the working of the Ion2Air unit is presented in appendix 12.

3.2.10 Cryo-condensation: Mariflex/purgit

and is based on cryo-condensation, which implies indirect cooling of the vapours to very low temperatures in heat-exchangers. The cooling is accomplished by evaporation of liquid nitrogen. The evaporated nitrogen can be led into the cargo tanks to expel the vapour from the cargo tanks and maintain an inert atmosphere (degassing and inerting during the same operation). The unit is provided with a second stage removal technique: regenerative activated carbon adsorption using the PSA principle. The cryo-condensation unit removes most of the VOC in the first stage and the activated carbon adsorption removes the remaining VOC to obtain a very high removal rate (up to 99,9%). Mariflex states that they can reduce VOC emissions from sea vessels and inland barges to a level that complies fully with existing environmental regulations. Currently the MVRU can process 600 cubic meters of gas per hour and remove 99,9 % of all hydrocarbons. Mariflex further states that they are improving the unit so that it can finally reach a capacity of 1100 cubic meters per hour. The size of the unit is suitable to be installed into a 20 feet TEU container and the weight is approximately 5000 kilo. Off course liquid nitrogen storage must also be supplied. Degassing of one 3200 m^3 barge requires approximately 9.300 litres of liquid nitrogen, when the cargo volume is "refreshed" two times (Royal HaskoningDHV, 2013). A flow-scheme of the working of the Mariflex unit is presented in appendix 13 (Robles, 2012).

3.2.11 Catalytic oxidation

Catalytic oxidation requires preheating of the waste gas to a temperature of at least 250°C. For most VOC's a temperature of 350 °C is required. The max. VOC-concentration is 10 g/Nm3. This temperature requires an inline-burner. Normally a heat-exchanger is applied. With this heat-exchanger a thermal efficiency of approx. 60 % is achievable. Also a heat-exchanger creates the possibility for autothermal operation at a waste gas concentration of 2.5 g/Nm3 (V.G. Aurich, MTSA process, 2005). A typical flow-scheme of a Catalytic oxidation unit is presented in appendix 14.

3.2.12 Washing

A system for the washing tanks is composed of pumps, sea water heaters,the condensate cooler, pipelines and washer nozzle. The system also includes the steam control valve located in the steam pipe conducted for heating. The amount of steam for heating is regulated by the output temperature of sea water from the boiler through the sea water temperature sensor. Condensate control valve that regulates the state of the
condensate through the float set to maintain the level of the exhaust pipe between the heater and condensate cooler. By a pressure pump sea water is supplied to the washing devices placed in each tank, so that by powerful jets cargo residues are removed from the tank surface. Prior to this, sea water is heated up to the required temperature through the condensate cooler and a steam boiler (Shell Report appendices, 2012). A typical flow-scheme of a washing unit is presented in appendix 15.

3.2.13 Vapour balance system

The vapour balance system principle is used when one tank transfers the liquid load into another tank and when this process is active, the vapours of the tank which is loaded is simultaneously transferred into the tank which is loading the liquid. The principle of a vapour balance system occurs from barge tank to barge tank and form barge tank to inland storage tank. This is only applicable when tanks have a fixed roof. When one of the tanks has a floating roof then the vapour must be processed with another degassing solution (Shell Report appendices, 2012). A typical flow-scheme of the working of the vapour balancing system is presented in appendix 16.

3.2.14 Biological treatment

Method of biologically filtering gases containing pollutants, in particular industrial waste gases by a fixed bed type filter material containing a carrier material which has been provided with appropriate micro-organisms which are stationary on the surface of the carrier material, characterized in that the gases are initially water saturated prior to their entrance into the filter material by bringing the gases into intimate contact with water in such manner that the gases contain the quantity of water required for the micro-organisms, to optimally function, the water saturated gases are then directed into the filter material and passed through it, whereby the pollutants in the water saturated gas come in direct contact with the micro-organism on the surface of the carrier material (V.G. Aurich, MTSA process, 2005). A typical flow-scheme of the working of the biological treatment system is presented in appendix 17.

3.3 Degassing techniques/specifications comparison

3.3.1 Degassing techniques specifications

All the previous stated degassing techniques, conventional methods and logistical solutions for the avoidance of degassing are assessed on key indicators which are in line with the importance of the specifications reasoned from a supply chain perspective point of view.

The different specifications are translated in an assessment based on:

- Availability: Measured on the basis of the operational state of the technique, if it is available for use or if it is in testing phase.
- Capacity: The theoretical throughput of what the relevant technique can process in terms of m3/h.
- Product variety: Specified as which (vapour)substance can the relevant technique process and which substances are proven to be a difficulty.
- Recovery: Whether there is a clean product recovery, a mixed product recovery or no recovery at all.
- Suitable platforms: which platforms are suitable for the desirable technique, which is specified in fixed on shore, floatable (near shore) or a on board technique.
- Dimension: The dimension of the technique, measured in total dimensions (in square meters).
- Cost estimate - (C)APEX / (O)PEX: A cost estimate divided in Opex, the operational costs, these are costs made by executing the relevant technique and are variable for each degassing cycle and Capex the capital costs, these are the costs made for the investment of the relevant technique.
- Average duration: This is the estimate of average time (in hours) it takes the relevant technique to sufficiently degas an inland vessel.
- Efficiency: Measured by the amount of VOS-removal can be realized for each relevant technique.
- Safety assessment: each technique is assessed on possible risks within the aspect of safety.
- Sustainability: This is assessed on all forms of sustainability, this is in form of emissions from sailing and from the use of the technique itself, extra adhesives when using a relevant technique and power use when processing vapours.

These specifications are displayed in appendix 18.

3.3.2 Degassing techniques balanced scorecard

The specifications from the previous sub-paragraph are ranked with the balanced scorecard principle. The advantages of the balanced scorecard principle are the ease of use for and it makes the benchmark between the various techniques measurable. The filled balance scorecard is displayed in appendix 19. The motive for the balancing of specifications is based on the impact which it has in the supply chain. The specifications: availability, sustainability, operational costs (Opex) and efficiency have a more heavy weighting, this is done by performing a sensivity-analysis over the set criteria. Availability is of great importance to separate the operational possibilities with the testing phased ones, concerning a short termed prohibition this is of great importance. Eventually all substances will be prohibited to degas in open air. This is why viewed from a long term development perspective, Operational costs and sustainability are of great importance within the supply chain. A possible solution must be rolled out for the future and be feasible to maintain on long term for all parties within the supply chain. The ranking of ‘sustainability’ can be interpreted on different levels. For instance for dedicated transport lies the environmental emissions in the extra covered distance and using fuel for it. The environmental emission for incineration are the added fuel for the incineration process, whether for other techniques the environmental emissions are measured in the use of power or the use of other additives within the process. All specifications are compared in their own manner exploiting specifications, this is the case for all the specifications. The results shows two clear ‘losers’: Biological treatment and catalytic oxidation, these techniques are not realistic to exploit. The balanced scorecard shows a range of promising techniques in theory, but on short term not very likely to be feasible for the degassing of inland tank vessels. Higher scored techniques are: The load on top principle (compatibility list), dedicated transportation, incineration, direct degassing, the vapour recovery system and adsorption (with regenerative use of activated carbon).

3.3.3 Degassing techniques SWOT-analysis

The technique specifications, balanced scorecard and trends within the inland tank transport and maritime sector give the input for a SWOT-analysis. The SWOT analysis forms the internal pro's and con's specific for each technique by formulated strengths and weaknesses. All other possible causes which will alter the effectiveness, use and capabilities of the relevant techniques. These are taken into account by the opportunities and threats. The outcomes of the SWOT-analysis are displayed in appendix 20.

3.4 Development of techniques

The development of techniques is an important point that has to be taken into account. The dynamics of the degassing problems are so rapidly changing that the observations done a year ago can be outdated in the current situation. The techniques which are in testing phase are: Micro gas wash, (Cryo-)condensation and Ionisation. The techniques which are in testing phase are all very promising in theory. What these techniques require are tests from which they can learn and adjust their technique and eventually reach the level of an operational usable technique to degas inland barges. However the entire market with all its actors of inland barge transport are waiting for the most suitable technique to be fit for their use and the technique suppliers are waiting of reaction and interaction of the market. Due to this construction the development of techniques improves slowly. Through initiatives, goodwill and the progressive insight of an upcoming direct degassing prohibition, the investment in degassing techniques with accompanying developments of techniques and the awareness of the impact of a direct degassing prohibition raises. An example of this trend is the growing number of barge(fleet)owners which make their barge available for degassing at the request of the technique deliverers/gas-processing parties. The reason for this slow improvement can be the low demand of barge transportation. Because of the low demand of inland tank transport, the barges do not have a direct consecutively order. Due to this unused time it is more likely to degas at the highest cost-effectiveness, instead of taking sustainability or duration into account, which in most cases leads to direct degassing. When the demand of inland tank transport increases the barge(fleet)owners will experience more importance in for instance the duration of degassing, which will eventually help developing the gas-processing techniques for mutual benefit.

From various expert judgments form the field of suppliers of degassing techniques and interviews with relevant stakeholders, the emphasis of the working efficiency of techniques is focused on the last remaining VOC-vapours. In the experience of gas processing units one could say 20% of the last remaining VOC-vapours is 80% of the total effort within the total degassing process. This problem has a high cohesion with the lack of clear legislation of a level of 'gas free', this has the cause that vapour levels are measured in various standards with different starting-points. This will be covered in more depth in the chapter: 'Active stakeholders and laws & legislation'.

3.5 Conclusions phase 2

All the major conclusions remarked in the chapter operations and substantively aspects concerning the degassing of barges are stated in this paragraph:

- The higher scored techniques are: The load on top principle (compatibility list), dedicated transportation, incineration, direct degassing, the vapour recovery system and adsorption (with regenerative use of activated carbon). This concluded from the outcomes of the balance scorecard with accompanying sensivity-analysis. The focal points of this method are the sustainability score of the technique, the availability of the technique and the operational costs of the degassing technique.
- The applicability of techniques based on the variation substances which can be processed can play a role in the eventual choice for certain techniques. When taking the phased prohibition of direct degassing into account, the prohibition states on short-term the ban of the degassing of benzene and highly benzene containing products. When the relevant technique cannot cope with these substances it is less suitable for short-term but maybe useful for different product streams on long term.
- The ranking of 'sustainability' can be interpreted on different levels. For instance for dedicated transport lies the environmental emissions in the extra covered distance and using fuel for it. The environmental emission for incineration are the added fuel for the incineration process, whether for other techniques the environmental emissions are measured in the use of power or the use of other additives within the process.
- The techniques which are in testing phase are all very promising in theory. What these techniques require are tests from which they can learn and adjust their technique and eventually reach the level of an operational usable technique to degas inland barges. However the entire market with all its actors of inland barge transport are waiting for the most suitable technique to be fit for their use and the technique suppliers are waiting of reaction and interaction of the market. Due to this construction the development of techniques improves slowly.
- Because of the low demand of inland tank transport, the barges do not have a direct consecutively order. Due to this unused time it is more likely to degas at the highest cost-effectiveness, instead of taking sustainability or duration into account, which in most cases leads to direct degassing. When the demand of inland tank transport increases the barge(fleet)owners will experience more importance in for instance the duration of degassing, which will eventually help developing the gas-processing techniques for mutual benefit.
- From various expert judgments form the field of suppliers of degassing techniques and interviews with relevant stakeholders, the emphasis of the working efficiency of techniques is focused on the last remaining VOC-vapours. In the experience of gas processing units one could say 20% of the last remaining VOC-vapours is 80% of the total effort within the total degassing process.

4. Active stakeholders and laws & legislation

4.1 Introduction

In this paragraph the laws and legislation are described on an international level, national level and a local level. This will show in unclear laws legislation within the scope of degassing inland tank vessels, also this phase will give an overview of legislation which is regulated or need to be regulated. this also includes the laws and legislation with regulation of re-use of chemicals within the supply chain. In addition an active stakeholder analysis was created which displays all parties within the degassing of inland tank vessels.

4.2 Current laws and legislation

4.2.1 International laws and legislation

Since 2006, all transportation modes are subject to a prohibition for degassing petrol under the Fuel Directive. Naphtha, benzene and many other hydrocarbons are currently not covered by this Directive. For the transport of inland tank vessels the fuel Directive, EC directive (94/63 EC) is active which means a prohibition for the direct degassing of UN1203 gasoline.

Based on (ADN, 2011) (European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways) focused on safety, degassing is allowed while sailing if this is not reasonably possible at a designated location. All substances may be degassed while sailing under the ADN, except:

- After loading gasoline (UN1203) because this is in conflict with the fuel directive.
- When direct degassing of toxic substances near bridges, locks and dense populated areas (which is not defined) within the ADN
- When degassing a non-toxic substance, then only a prohibition to degas near locks is active.
- When a vessel is moored, a prohibition for direct degassing is active, unless a location is designated by competent authority.

The Strasbourg Convention on the Collection, Deposit and Reception of Waste during Navigation on the Rhine and Inland Waterways (CDNI, 2012) is an international treaty which has been adopted by six countries, (in their national legislation), which are active for navigation on their inland waterways (Belgium, France, Germany, Grand Duchy of Luxembourg, the Netherlands and Switzerland). The main objective of this Convention is to protect the environment and to improve safety in inland navigation. To achieve this objective, the Convention aims at improved checking of any waste that occurs, specifically through:

- Safe and separate collection and subsequent disposal of wastes arising from operating the vessel;
- Requiring those causing wastes to pay the costs of collection and disposal;
- The application of uniform regulations within all signatory states of the Convention in order to avoid any unfair competition.

The CDNI can be divided into three main waste categories. The implementing regulations make a distinction according to the origin of the waste occurring on board (Van Meel, G., 2014):

- Part A Oily and greasy waste produced in the course of operating the vessel
- Part B Waste connected with the cargo
- Part C Other waste generated by operating the vessel, including sewage and garbage

The regulations also take into account the corresponding responsibilities. Some rules are addressed to the boat master, as in the case of oily and greasy waste, household waste and special waste. Others impose obligations on the charterer or the addressee of the cargo.

4.2.2 National laws and legislation (The Netherlands)

The competent authority inside the dock-basins is the Harbour Master. The competent authority outside the dock-basins is Rijkswaterstaat (the Dutch Department of Waterways and Public Works). The the Dutch Department of Waterways and Public Works will not give a permission for moored direct degassing outside the dock-basins and therefore no locations are designated by Rijkswaterstaat. The only options for moored direct degassing outside the dock-basins is in case of calamities. Rijkswaterstaat can give authorization (even for gasoline, UN1203) for moored direct degassing and has appointed eight locations (based on wind and meteorological conditions) for these emergency direct degassing situations. This permission has never been granted by Rijkswaterstaat.

4.2.2.1 Local laws and legislation (Port of Rotterdam)

Under the Rotterdam Port Management regulations, a prohibition applies to degassing tank vessels in the harbour, unless this takes place in closed tanks and at a designated berth. Degassing at terminals is only permitted if environmental permit allows, or if the degassing is done via vapour treatment systems. There is one possibility to degas moored, in the Geulhaven (Buoys 60) which is designated for degassing operations after permission from Harbormaster. The harbor master gives permission to approximately 700 vessels yearly which results in between 1 and 2 vessels every day. Prohibited to degas moored inside the dock-basins are thirteen substances which are incorporated in a list of smelling/nuisance substances according to the (PoR Harbour regulations, 2010) article 8.2 (paragraph 4) and 10.1 (paragraph 8). Degassing in the Port of Rotterdam can also be prohibited when a nuisance code is applicable. When a notification of odour nuisance is notified DCMR (the DCMR is the environmental protection agency of local and regional authorities in the Rijnmond region) can activate a nuisance code. When the nuisance code is active major industries must take temporary measures to reduce their air pollution in the Rijnmond area. In this case direct degassing, sailing or moored is prohibited.

4.2.2.2 Local laws and legislation (Port of Amsterdam)

The conditions during which degassing is allowed in the port of Amsterdam are similar to the conditions of the port of Rotterdam. Degassing may be restricted or prohibited if the atmospheric conditions are such that due to the release of these substances danger, damage or hindrance occurs or could occur under those conditions.
This results in whether there is an air quality code (nuisance code) in force? If so, degassing is prohibited. This code is set by the Province Noord-Holland (the regional environmental authority). It is prohibited to direct degas moored inside the dock-basins unless location is designated by competent authority. With exception of the thirteen substances which are in line with the list of smelling/nuisance substances according to the Port harbor regulations. Inside the dock-basins no locations for moored degassing are designated by the port authority.
Furthermore the following local conditions apply:

- Will the ship reload in Amsterdam? If not, no permission for degassing is granted, this is verified by the Harbour Master at the terminal
- Is there an appropriate berth available? If so, a berth is appointed by the Harbour Master (the competent authority)

4.2.3 National and local laws and legislation (Belgium – Port of Antwerp)

Inside the dock-basins of the river Schelde in Antwerp, a degassing prohibition applies if VOCs are emitted. Additionally, degassing may only take place after permission of the harbourmaster. On the Schelde itself, degassing is allowed. Gas-freeing of dangerous substances of Class 2 or Class 3, with a classification code including the letter "T" in column (3b) of Table C of Chapter 3.2, Class 6.1 or packing group I of Class 8, may be carried out only at the locations approved by the competent authority according to (ADN, 2011) legislation. Gas-freeing of other dangerous substances may be carried out while the vessel is underway or at locations approved by the competent authority and is prohibited within the area of locks including their lay-bys. This has been implemented in national and regional law in Belgium.

4.2.4 National and local laws and legislation (Germany)

In Germany, not only does a degassing prohibition apply to gasoline (UN1203), but also to mixtures of gasoline and ethanol (UN 3475) and for petroleum distillates or petroleum products (UN1268). Germany has allowed the degassing of benzene while sailing. A more strict prohibition is active of the direct degassing of inland tank vessels in comparison with the neighboring countries, however it is not regulated on the waterways of Germany by the German authorities. Although there is no regulation of the active direct degassing prohibitions in Germany, the barge(fleet)owners postpone the direct degassing within the German waterways and start direct degassing when passing the border and reaching The Netherlands or other countries which have a less strict direct degassing prohibition. This creates a flow of liquid free vessels which need to be degassed, this can be described as 'direct degassing tourism' which takes place. To avoid this 'direct degassing tourism', the direct degassing prohibition must be applied on an international or European level in an uniform manner. If this is the case the prohibition could be applied by a directive as the fuel directive or be part of the CDNI or ADN.

4.2.5 Regulatory uncertainties within degassing of inland tank vessels

In the Netherlands European environmental directives related to air pollution are implemented in the Environmental Management Act and the Activities Decree. Industrial Emissions Directive which regulates emission from large industrial sources is implemented in the Activities Decree. This Directive sets rules for large combustion plants, waste incineration plants, VOC solvents and IPPC-installations. Emissions which are not regulated by the general binding rules of the Activities Decree, are subject to permits. The emission limits for most substances that are emitted to air by industrial sources, are given by the Netherlands Emission Guideline for Air which is the guideline called NeR, (NeR, 2013). The General Provisions of Environmental Law regulates the environmental permits. The environmental permit is one integrated permit which contains permits for: construction, residential issues, monuments, nature and environment, which is called the WABO, (WABO, 2013).

Due to the different levels of laws and legislation and different perspectives/purposes of the interpretation of degassing it is unclear about when a vessel can be declared ‘Degassed’. The standards which is used is the standard described in the ADN, which is the level of <10% of the lowest explosion limit (LEL), this legislation is from a safety point of view. When an inland tank vessel declared to be < 10% LEL it experienced as ‘degassed’. This differs from an environmental point of view and must be seen in separate perspective. An environmental point of view are stated in the NeR (The Dutch emissions guidelines) and the WABO (The General Provisions of Environmental Law). These demands state the emissions to be minimal and in the case of substances which have a high toxicity level the NeR states the emission level must strive to an emission level of zero. These different perceptions of degassed create a confusion throughout the supply chain.

The problem in addition to the problems within the definition of ‘degassed’, is the lack of clear laws and legislations to which a floating degassing installation (placed on a pontoon) must suffice. This lack creates not only a unclear perspective about the level of degassing, but also an unclear perspective of the technical, safety and environmental demands to which a floating degassing installation must suffice. This makes the task of the provider of the relevant degassing techniques to create a suitable platform for a applicable degassing technique more complicated.

4.3 Re-use of chemicals

In this paragraph the interpretation of re-use and recovery of chemicals towards government bodies is exhibited. To realize an effective re-use of chemicals the current laws and legislation must be in line with the operational re-use of chemicals. An essential aspect concerns the qualification of the cargo vapours, respectively the liquefied gaseous residues in terms of waste treatment. Liquefied vapours and gasses from previous cargos should therefore not be defined as waste. In this order the respective volumes could be reintegrated in the supply chain. The procedures and reglementary framework should be in line with the re-use of chemicals principle. Appropriate consultations and adjustments of the competent authorities and regulation of laws and legislation ought to clarify and validate this re-use of chemicals principle.

A vital element within the re-use of chemicals principle is the degassing as a physical operation, which needs to be seen as a disconnected part from the unloading procedure. However, degassing is an aspect of the total physical distribution as such. The responsibility for the correct execution of the degassing and the delivery of the degassed cargo tanks therefor needs to be specified in which parties are responsible for which operation within the supply chain. The shared responsibility of parties in the supply chain needs to be worked out in a detailed level, taking into account the need of collaboration, transparency and market uniformity in the supply chain, before legal obligations and regulated laws and legislation can be introduced.

4.4 Active stakeholders

In order to describe the context and the boundaries of this new business, several issues and uncertainties should be addressed properly, such as: All identified uncertainties linked to these types of aspects will be investigated in order to ensure a feasible scheme focused on 'Smart Logistics and a sustainable solution', supported by all relevant stakeholders which are displayed in the stakeholder analysis in figure 14. Organisations are realising the need for recognising the larger community in which they operate, specifically in terms of supply chain management (Harrison, A. Hoek, R. van, 2008). Local and national goverment bodies, local communities and industries, and extended branch organisations respresnt part of this larger group of stakeholders that cannot ignored in terms of their importance in day-to-day business.

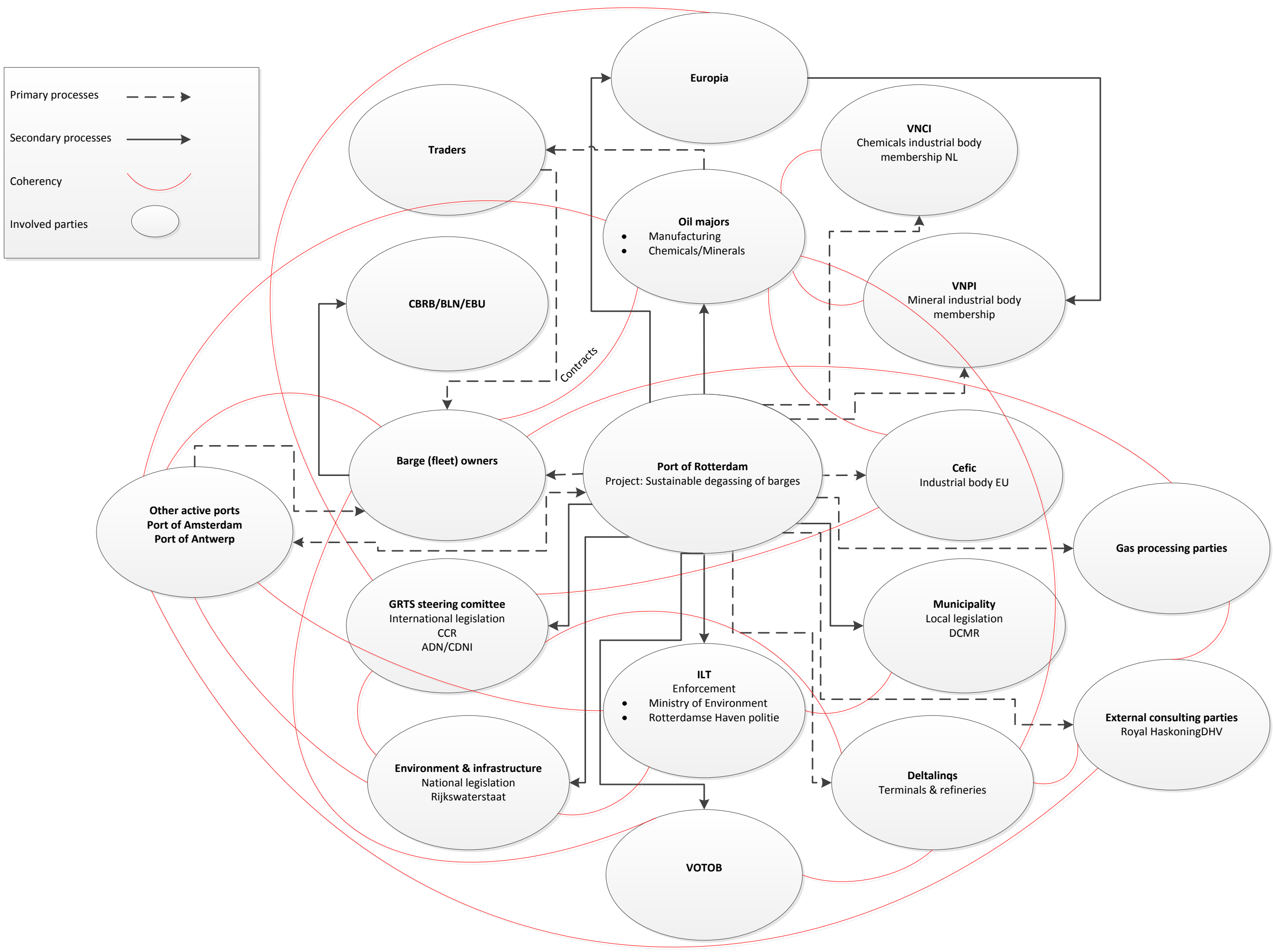

Figure 14: Stakeholder analysis

The playing field concerning the degassing of inland barges is intransparant and complicated. There are many parties with in some cases mixed interests. This can have negative consequences for the collaboration and transparency between parties. All the functions of all stakeholders and actors which are involved within the dynamics of the degassing of inland tank vessels are displayed in appendix 21 in the 'Stakeholders/actors functions'.

4.5 Degassing decision tool

To function as a guideline for the implementation of the laws and legislation for the direct degassing prohibition a decision tree was created. This decision tool is divided in five phases. The first phase is the substance related phases, in this phase the substance is based on the UN-code and description assessed on various traits such as: VOC traits, CMR traits, degassing priority, segment of the total emissions, lowest explosion level, vapour pressure and nuisance. The environmental aspect is represented in the second phase which contains environmental influences such as: nuisance codes, natural conditions, supplementary conditions and the distance from densely populated areas. The phases three and four are more aimed at the possible solution of controlled degassing. In the third phases the extra specifications are taken into account such as: dedicated transport, compatible substances, the demand of inert vessels, possible recovery of product and the potential loss of quality of the product. This will result in a technique which can be used in the fourth phase, solutions. The final result in the fifth phase needs to be either an inert vessel or a sufficiently degassed vessel. If this is the case the vessel is ready for the next load, if this is not the case the decision tool redirects automatically to the first substance phase. The decision tool is graphically displayed in appendix 22.

4.6 Conclusions phase 3

All the major conclusions remarked in the chapter operations and substantively aspects concerning the degassing of barges are stated in this paragraph:

- Due to the different levels of laws and legislation and different perspectives/purposes of the interpretation of degassing it is unclear about when a vessel can be declared 'Degassed' or 'vent-free level'. The standard which is used are the standards described in the ADN, which is the level of <10% of the lowest explosion limit (LEL), this legislation is from a safety point of view. This differs from an environmental point of view and must be seen in separate perspective. An environmental point of view are stated in the NER (The Dutch emissions guidelines) and the WABO (The General Provisions of Environmental Law).
- There is lack of clear laws and legislations to which a floating degassing installation (placed on a pontoon) must suffice. This lack creates not only a unclear perspective about the level of degassing, but also an unclear perspective of the technical, safety and environmental demands to which a floating degassing installation must suffice. This makes the task of the provider of the relevant degassing techniques to create a suitable platform for a applicable degassing technique more complicated.
- The playing field concerning the degassing of inland barges is very complicated. There are many parties with in some cases mixed interests. This can have negative consequences for the collaboration and transparency between parties.
- To realise an effective re-use of chemicals the current laws and legislation must be in line with the operational re-use of chemicals. An essential aspect concerns the qualification of the cargo vapours, respectively the liquefied gaseous residues in terms of waste treatment. Liquefied vapours and gasses from previous cargos should therefore not be defined as waste. In this order the respective volumes could be reintegrated in the supply chain. The procedures and reglementary framework should be in line with the re-use of chemicals principle.
- A vital element within the re-use of chemicals principle is the degassing as a physical operation, which needs to be seen as a disconnected part from the unloading procedure. However, degassing is an aspect of the total physical distribution as such. The responsibility for the correct execution of the degassing and the delivery of the degassed cargo tanks therefor needs to be specified in which parties are responsible for which operation within the supply chain. The shared responsibility of parties in the supply chain needs to be worked out in a detailed level, taking into account the need of collaboration, transparency and market uniformity in the supply chain, before legal obligations and regulated laws and legislation can be introduced.
- Although there is no regulation of the active direct degassing prohibitions in Germany, the barge(fleet)owners postpone the direct degassing within the German waterways and start direct degassing when passing the border and reaching The Netherlands or other countries which have a less strict direct degassing prohibition. This creates a flow of liquid free vessels which need to be degassed, this can be described as 'direct degassing tourism' which takes place.

5. Risk setting/appointing

5.1 Introduction

In this chapter all the risks are appointed within the feasibility study in the frame of a risk analysis model. Which specific risk model was used and what drives these risks will be analysed. The input for this chapter are the conclusions which are drawn in the previous chapters and are graphically displayed in figure 15.

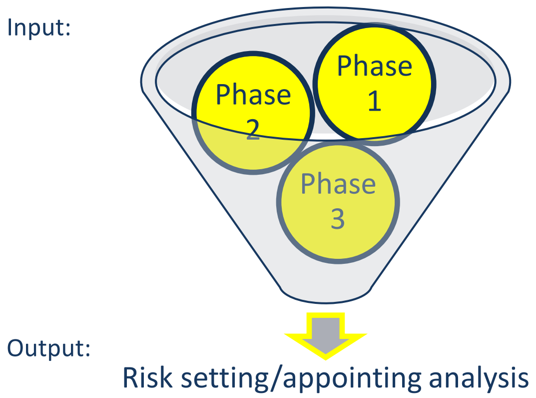

Figure 15: The correlation between used phases within this project

The aim of chapter is to provide a method to evaluate supply chain risks that stand in the way of the supply chain objectives. The model will be helpful in creating awareness of the phased prohibition of the direct degassing. The involvement of stakeholders from different areas is essential in establishing a thorough consideration of critical issues in determining a complete risk analysis.

5.2 Supply chain risk modelling

Supply chain risk has been defined as “any risk to the information, material and product flow from original suppliers to the delivery of the final product” (Christopher, 2011).
Risk factors can be considered in terms of:

- What drives the risk
- Where the risk is
- What the risk is associated with

Supply chain risks and supply chain risk factors can be identified in various ways, depending on the perspective which is adopted. However, supply chain risk assessment should be linked to the specific objectives of the supply chain which should guide the selection of risk indicators. In this feasibility study a model for assessing risk in supply chains based on the analytic hierarchy process (AHP) is used. The AHP supports in prioritising the supply chain objectives, identifying risk indicators and assessing the potential impact of negative events and the cause-effects relationships along the chain. Another supply chain risk model is the COSO ERM model. The perspective of enterprise risk management (ERM) is a relative new approach to risk management (Steinberg, Everson, Nottingham, & Martens, 2004). It attempts to manage both financial risks and operational/strategic risks, its perspective is more corporate based It is concerned with monitoring and managing risks to provide reasonable assurance to stakeholders regarding the achievement of company objectives. The ERM philosophy takes tools and methods of managing financial risk and adapts them for non-financial risk (COSO, 2004). The main reason why the AHP method was used for this feasibility study is because the COSO ERM model is more applicable for corporate environments. Whether the AHP model is more suitable for using in a more broad supply chain perspective or in specific projects when the aim is to identify and manage supply chain risks that threaten the success of a project.

5.3 Risk setting/appointing with AHP method

This model treats supply chain risk management as a process that supports the achievement of supply chain management objectives, which in this case is the feasibility of a phased direct degassing prohibition. In this sense, risk management is an integral part of supply chain management (Borghesi, A. &Gaudenzi, B., 2006)

For the purposes of this feasibility study, the supply chain was broken down to six areas, as defined in figure 9 in 2 chapter: 'Logistics, Barge transport and flow of product streams'. Those areas were defined as:

- Shipper
- Filler
- Trader
- Expeditor
- Charterer
- Receiver

The major supply-chain objective in the model was the assessment of risks within the supply chain concerning the feasibility for the prohibition of direct degassing. This was driven by three critical elements of feasibility, which are represented in the sub-objectives of the supply chain. These sub-objectives are in line with the previous chapters with corresponding names. These sub-objectives were:

Sub objective	**Chapter**
• Operational feasibility	Logistics, Barge transport and flow of product streams
• Technical feasibility	Operations and substantively aspects
• Laws & legislation feasibility	Active stakeholders and laws & legislation

Risk indicators were identified in each area particularly with a view to achieving the objective of feasibility of the phased prohibition of direct degassing which is displayed in figure 16. Each area was affected by different risk factors, depending on the sub-objectives. The aim of the model was to provide a method to identify a panel of risk indicators that could be applied at various levels of the chain.

Figure 16: Supply chain risk objectives and areas, the basis for the risk assessment

The AHP method has been useful moreover in setting up a priority hierarchy for risk treatment. That prioritization in managing risks depends on the importance of the objectives they affect. That importance could be initially defined using the AHP method.

To prioritize the objectives, the individual goals of different stakeholders were taken into account. The AHP method was used to prioritize objectives, and to match these prioritized objectives with different perspectives. Various AHP steps are undertaken:

- An assessment of criticalities affecting the objectives in order to assess their importance
- A quantitative evaluation of the importance of each objective, compared with every other objective
- An assessment of the weights for the objectives is processed.

After defining the objectives and areas, a set of criticalities in the achievement of the objectives can be defined. That critical points should be used as drivers in quantifying the priority of objectives and potentially, in the next step, as drivers in risk evaluation. At the second and third steps of the AHP method the comparison between objectives is defined. It means answering the question: which of the objectives is more important and how strongly, using a numerical scale? All the comparisons should be consequently checked in order to assure the consistency and the coherence of the evaluation. Setting up a panel of weights for the objectives helped in: defining which risks were more serious and Building the priorities in managing risks.

In accordance with the AHP method of ascertaining the prioritization of objectives, criticalities and risk factors which affect the supply chain goals are defined, these criticalities are displayed in figure 17 below.

After setting criticalities, a panel of indicators are defined that show the relationships within the supply chain, in which the selected risk factors which are assessed in terms of their impact on the stated objectives. Risk impact are assed based on a scale from 1 till 5, 5 meaning a great direct impact and 1 meaning the almost no direct impact. This panel of risk indicators is displayed in appendix 23.

Figure 17: Criticalities: criteria for setting the importance of the objectives and 'drivers' for evaluating risk factors

Subsequently defined is the level of the importance of the objectives from their own perspectives. In this manner a provided quantitative prioritization of objectives comparing the importance of each objective is created. In evaluating the ratios, the potential impact of events, and the cause-effect relationships within the supply chain will form an evaluated attribution for each objective. This evaluated quantitative prioritization is displayed in figure 18 below.

Objectives	Operational feasibility	Technical feasibility	Law & legislation feasibility	Sum +1	attribution
Operational feasibility	1	0,5	0,5	**2**	**36%**
Technical feasibility	0,5	1	0	**1,5**	**27%**
Law & legislation feasibility	1	0	1	**2**	**36%**

Figure 18: Evaluated quantitative prioritization of objectives

5.4 Conclusion phase 4

The outcomes of this risk analysis are represented in two figures, the risk factors were assessed in terms of their impact ("high" "medium" or "low") within the defined level of the importance of the objectives. The dependencies and correlations between factors and the cause-effect relationships when taking the objectives into account are illustrated with a flow chart, displayed in figure 19 below.

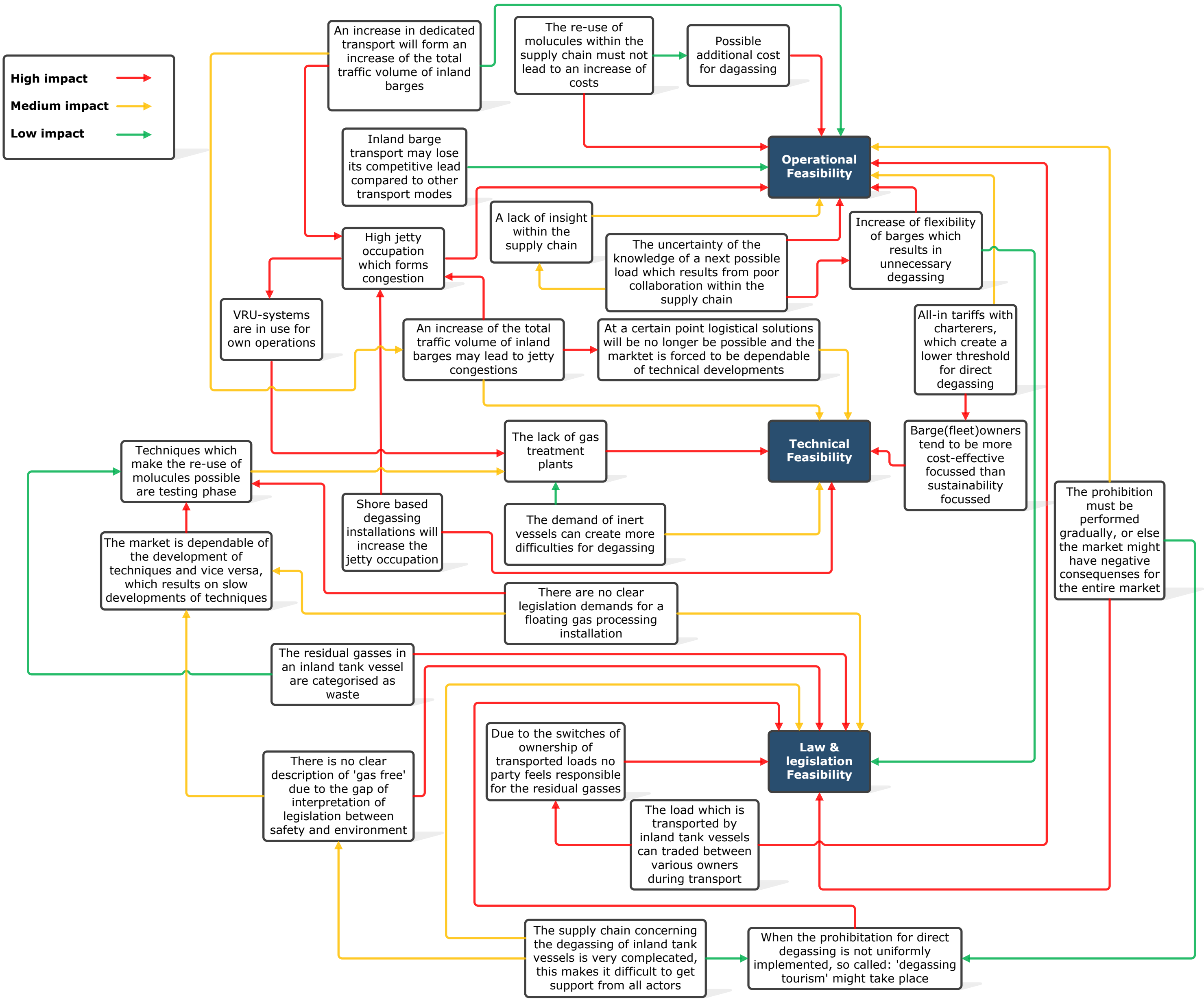

Figure 19: The correlations of risk factors with supply chain objectives

The representation of those potential effects and dependencies should be fitted into the supply chain point of view in terms of areas and objectives. A matrix is constructed that takes into account supply chain areas, objectives, and risk factors. The final results of the model are compared in a risk landscape in figure 20 and represented in the supply-chain areas and objectives. An appreciation of the most critical areas comes from careful evaluations of the impacts and a consideration of the cause-effect relationships which are displayed in the correlations of risk factors with supply chain objectives.

The research goal was to develop a model to assess risks in the supply chain and to involve the AHP method in the definition of decision priorities. The model will create awareness of supply chain risk factors within the feasibility of implementing the phased prohibition direct degassing of inland tank vessels. This is done by establishing a thorough consideration of critical issues and interdependencies in determining a complete risk analysis.

Objective	Shipper	Filler	Trader	Freighter	Charterer	Receiver
Operational feasibility	🟢 0,7	🔴 1,5	🔴 1,8	🔴 1,5	🔴 1,5	🟢 0,7
Technical feasibility	🟡 0,8	🟡 0,8	🟢 0,0	🟡 0,8	🔴 1,2	🔴 1,2
Law & legislation feasibility	🟡 1,1	🔴 1,5	🔴 1,8	🔴 1,5	🔴 1,8	🔴 1,5

Risk level	Symbol
High risk level	🔴
Medium risk level	🟡
Low risk level	🟢

Figure 20: Risk landscape per objective and supply chain area

The conclusion which can be drawn from the risk-analysis is in line with the previous conclusion of the previous executed research phases. Through the risk landscape it becomes visible that the highest risks lie in the law & legislation feasibility and in the operational feasibility. The most severe risks within the supply chain lie within the charterers area. This is the area with the least insight within the supply chain. Additional the charterers, (barge/fleet)owners hold the physical problem (the residual vapours), this creates the highest risks.
The operational, technical and legislation feasibility have a high cohesion with each other, mostly in form of a cause-effect relation. This makes the supply chain concerning the prohibition of direct degassing very complicated. From the conclusions which are strengthened in visibility, insight and cohesion of risks within the supply chain by the risk-analysis. Two scenarios are developed in the 'Financial aspects and profitability' phase taking into account the risks which are appointed.

6. Financial aspects and profitability

6.1 Introduction

In this chapter it will be described which financial scenarios can be developed and how can these scenarios be executed, taking into account the risks which are formulated in the previous chapter. An estimate of the increase in dedicated transport and compatibility which will lead to a decrease of the additional number direct degassing barges which is specified will be covered. Finally this will be compared with the current designed supply chain and two new scenarios will be formulated which can be assessed on feasibility of the phased direct degassing prohibition.

6.2 Increase in dedicated transport and compatibility

Compatibility seems to be the most cost effective manner to bypass degassing of barges after a prohibition, however this is in some cases not used as solution because of a presumed loss of quality of the product which is transported. Other options are the use of techniques at installations, either on board or fixed (on shore or floating) or the use of dedicated transport. Estimates are used accompanied with calculations in this paragraph to create an economic trade-off between controlled degassing at an installation versus dedicated transport. Assumed is that a prevalent ship is used which has, according to (Rijkswaterstaat (DVS), 2012) an average width of 13,5 meter, an average length of 110 meter, an immersion of 4 meter (loaded) and a loading capacity of 4001 to 4300 tons average. The prices of this prevalent ship are specified in single hulled ships, RVS and coated ships. A weighted average was made of these prices based on the occurrence of the specified ships within the European fleet according to (IVR, 2013). The parameter within this trade-off is the amount of kilometer form shipper to receiver. Used as degassing costs is € 3000,- as an average and there is assumed the degassing has an average duration of eight hours. Between the unloading and the arrival at the degassing installation and between the degassing installation and the destination of the next load there is estimated to be a (unloaded) sailing time of four hours average. The waiting time of a barges is included and is estimated to be two hours before loading and unloading, which is taking into account within the total transport time and cost. These outcomes are chronological displayed in figure 21 below and are measured form loading an empty barge till the barge is ready for its next specified load. The overview of the calculations which are made for this trade-off can be found in appendix 24, where the costs are measured form the Port of Rotterdam to central locations in the ports of Amsterdam, Antwerp, Düsseldorf, Koblenz and Basel. These distances to the various ports give a good dispersion of relatively short transports and relatively long transports. These distances are obtained via an inland waterway route planning tool which includes average passing times locks (Periskal, 2014).

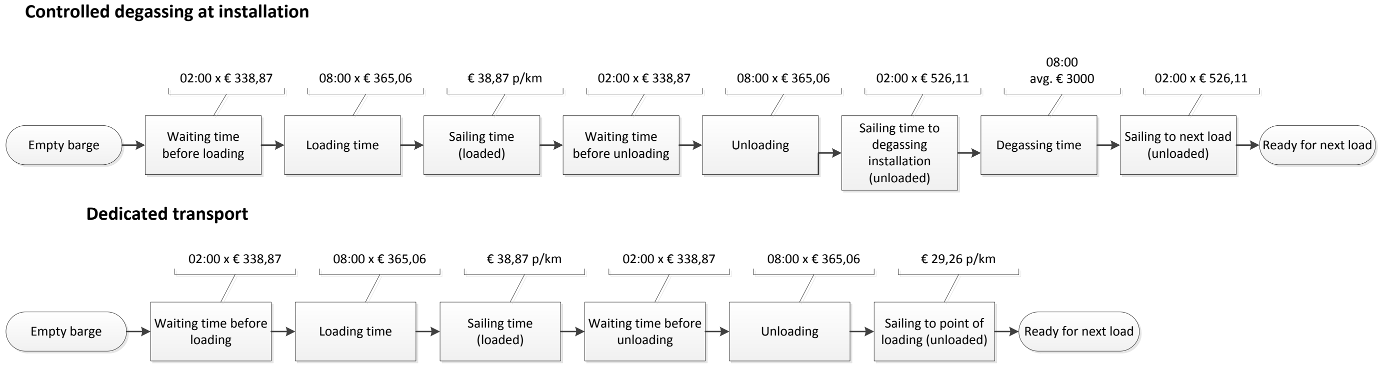

Figure 21: Trade-off, controlled degassing versus dedicated transport

From this estimates and calculations the economic trade-off can be formulated into a formula, in which is variable 'X' is specified to be the amount of kilometers which have to be covered within the transport.
The formula is formulated as: *"Controlled degassing = Dedicated transport"*.
Which results in the numerical formula: *"38,87X + 12.300,89 = 68,13X + 7.196,45"*.

The outcome of this formula gives the insight that when the total transport is more than 174,45 kilometer, controlled degassing is a more profitable solution than dedicated transport. However this result has to be seen in a perspective, what has to be taking into account is the substance which is transported. Dedicated transport is a longer process with occupies the chartered barge. If the next sequential transport of the chartered barge is near the area of the degassing installation and that transport requires a sufficiently degassed ship. It is more profitable to perform a controlled degassing at the degassing installation than dedicated transportation, however this requires a good planning of sequential transport which requires insight within the supply chain. The raise in dedicated transport is based on the estimated amount of relatively short transportation flows and additional the compatible substances which are loaded on top more frequently. Estimated is that the dedicated transport will increase by 10% and for the compatible substances the raise is dependable on the compatibility of the next load, exact amounts per substance are specified in appendix 25. All barges which are not sail dedicated or load on top compatible substances need to be degassed. If the transported substance is prohibited to be direct degassed a controlled degassing must take place. The demand is based on phased prohibition displayed in figure 1, this demand is cumulative displayed below in figure 22.

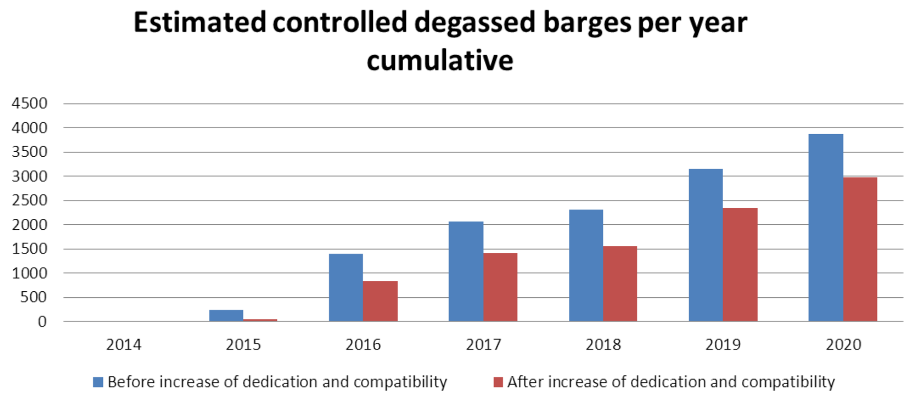

Figure22:Estimated cumulatively controlled degassed barges per year

This estimated increase in dedicated transport and compatibility will lead to a decrease of the additional number direct degassing barges which is specified figure 23 below.

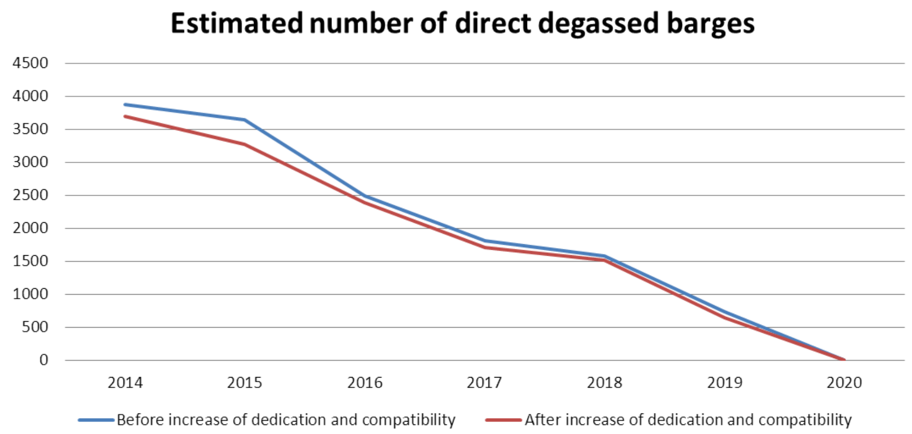

Figure 23: Estimated direct degassing of barges effected by the increase of dedicated transport and compatibility

These estimates and assumptions in this paragraph can be concluded by the amount of gas processing units which correspond with the estimated amount of controlled degassing of barges displayed in figure 24 Below. These results based on an estimate that a gas processing installation can degas two ship per day, which results in approximately 730 barges which can be degassed per year per degassing installation.

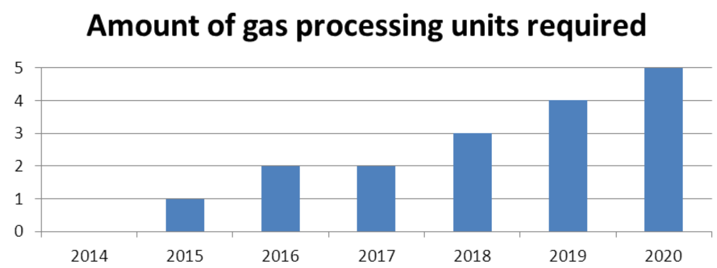

Figure 24: Total amount of gas processing units required

6.3 Feasibility supply chain design

In the previous paragraph the total demand for controlled degassing is displayed in phases. This paragraph uses this as input by stating two possible scenarios of a new supply chain design concerning the degassing of barges on a more sustainable way, which is in line with the assumed phased prohibition.

6.3.1 Current supply chain design

To give insight in the working of the two new supply chain designs concerning the degassing of barges there must be a clear overview of the current supply chain design. Graphically displayed in figure 25 is the current supply chain design. The green streams represents the financial flow within the supply chain, the red streams represents the information flow within the supply chain and the black streams represents the goods flow. Within the goods flow a distinction is made in liquid goods flow (which is the solid black stream) and residual (vapour) goods flow (which is the striped black stream). Numbered form 1 till 6 are the contracts affect the process of degassing. The first contract which is made is based on the agreement of the selling of chemical feedstock, this is the contract between the shipper and receiver. This could be a contract for longer term or an incidental contract which agrees on a delivery of chemical feedstock in a certain quantity and on a certain date at the receiver. When this is completed, the receiver pays the agreed price to the shipper. The shipper may have calculated storage of the goods in the total price form which the shipper pays a potential filler within the supply chain, this contract is marked as contract 2 in the figure. The shipper makes a contract with a shipping company/expeditor to arrange transport for the quantity of goods and time of deliverance, this is specified as contract 3 in the figure. The shipping company arranges a chartered barge which can be used and loaded with the product at the most efficient way possible, this is specified as contract 4 in the figure. This is done under the conditions of documents as:

- Terms and conditions of transport, by the (Federal Association of German Inland , 2010)
- International Conditions of Loading and Transportation, by (IVR & VWB, 2010)
- Schweizer Rheintransport-Bedingungen, by (Schweizerischen Vereinigung für Schifffahrt und Hafenwirtschaft, 2009)
- Conditions of Carriage, by (CBRB, 2013)

These contact formats, which are used have not specific legislation and/or clauses concerning the liability or responsibility of degassing barges. When via one the previous stated contracts an agreement is made with a chartered barge the barge collects the goods at the filler(tank storage companies) on an agreed date and in the agreed quantity, this is specified as contract 5 in the figure. Then the chartered barge delivers the agreed quantity at the agreed time at the receiver, which is specified as contract 6 in the figure. At this moment the barge has the residual vapours which possibly need to be degassed for the next transport. The barge owner/charterer has a number of options which are previous specified in this feasibility study, if the substance which is loaded next is not compatible with the previous load and dedicated transport is not in order, there are two options. These options is controlled degassing which has additional costs (what the green stream implies) or the charterer can choose for direct degassing.

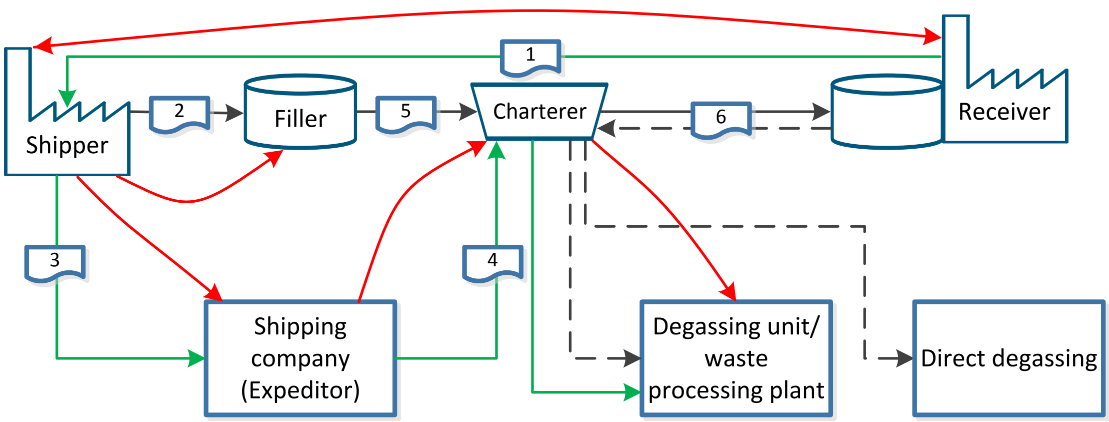

Figure 25: Current supply chain design concerning the degassing of barges

6.3.2 New supply chain design scenarios

The scenarios which are formulated are based on the prohibition of direct degassing and are therefore more sustainable designed supply chain scenarios which support to implement a well working financial structure within all stakeholder in the supply chain. The first scenario in which feasibility of sustainable degassing can be realized is graphically displayed in figure 26. The key to this scenario is intervene as little as possible within the existing supply chain. The largest impact of this in this scenario is that direct degassing is no longer possible, this creates a situation when degassing is necessary the charterer must perform a form of controlled degassing. This makes the content of the contracts which are specified more important. The responsibility of the residual vapour in the barge must be appointed to a party in the supply chain in form of contracts and thereby the costs for degassing must be appointed based on contracts which can be handed over. In this case the responsibility and liability within the supply chain cannot be evaded through contracts. In this manner the supply chain becomes more transparent and can solve the additional costs of controlled degassing by calculating the extra costs of controlled degassing in their margins through the entire supply chain. Most likely effect of this scenario can be best elaborated by following the green arrows in the figure in the other direction to which the financial streams flow. The charterer finances the degassing costs, due to this finance the margins of the charterer increases. Due to this increase of demanding price the price raises with a certain margin throughout the entire supply chain. This eventually results to a minimum increase of the margin of the final product at the end of the supply chain. Taking into account in this scenario is the re-use of the vapours, when the promising techniques with the re-use of chemicals are operational, an agreement can take place between the charterer and the shipper to make use of the recovered product. This must also be registered as transparent as possible via contracts which can be handed over, this is specified in the figure as contract 7. When the product cannot be recovered is can be controlled degassed (and destroyed) directly or the recovered product can be processed and destroyed at a waste processing plant.

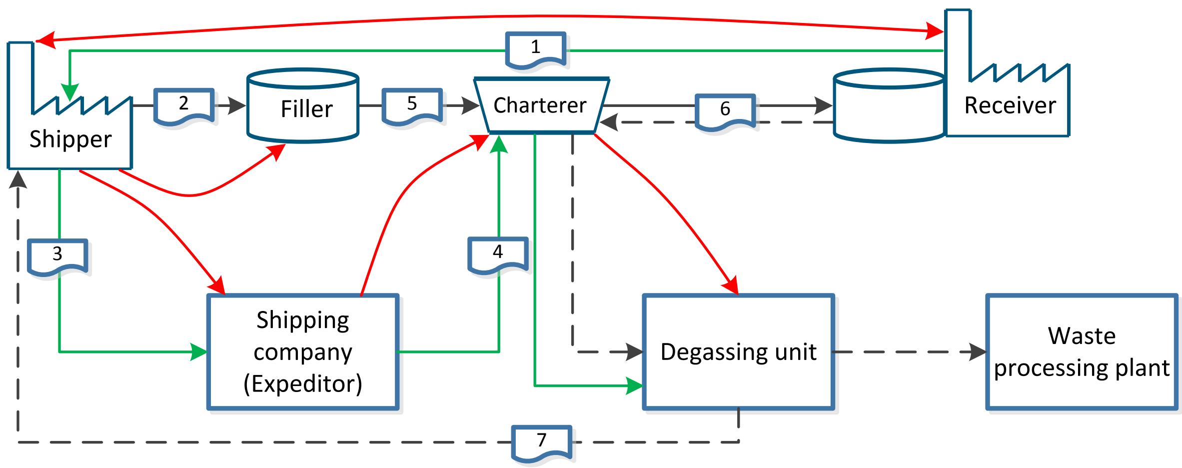

Figure 26: Supply chain design scenario 1

Through this scenario the investment/capital costs are not focused on one actor in the supply chain, this has an advantage in implementing. The degassing units are not funded by external, municipalities, overarching or additional branch parties concerning the degassing problem. An possible advantage is that this scenario will solve the degassing issue quick and as efficient as possible because everyone in the supply chain is direct financial involved in the compliance of the prohibition. This could has as consequence that the entire responsibility of product, information and financial flows of supply chain stakeholders is shared. However the overarching parties such as the Port of Rotterdam and municipalities should regulate that the amount of existing gas processing units match the required gas processing units which are in line with the estimated demand of barges which need to be degassed. By letting the costs of degassing be divided over the entire supply chain, parties will take actions to reach forms of supply chain collaboration to reduce their costs, in this manner the entire 'degassing problem' will solve itself partially.

The second scenario involves a non-profit orgainsation which is based on a construction of a removal price which covers the operational costs for the controlled degassing, which is graphically displayed in figure 27. This non-profit orgaisation is the link between the degassing process (which is the physical end of the supply chain) and the shipper (which is the physical begin of the supply chain). When the shipper makes a contract with the expeditor/shipping company, an additional contribution is taking into account within the contract which the shipper has with the non-profit organization, this is specified in the figure as contract 3. This contribution must be reconciled with the gas processing parties. This contract is between the shipper and gas processing parties, with the non-profit organisation performing in an intermediary role. In comparison the non-profit organization, which can be filled in by instances as: Ports, municipalities or other overarching parties is now fully responsible for the financing the implementations of gas processing units. For the promising techniques with recovery of chemicals it can be taking into the contract between shipper and gas processing parties who is responsible for the recovered product which is specified in the figure as contract 9. The advantage of this this supply chain design is that the charterer is now not responsible for the additional degassing costs. The challenge of this design is that the shipper and degassing units are forced to have a form of supply chain collaboration and the pricing of degassing must be regulated so the gas processing parties cannot take advantage of the lack of knowledge of degassing pricing. This must be validated in a way, which will have more additional cost. By bringing an extra (non-profit) organisation in the supply chain it does not become less transparent and also it will be difficult to find parties which will investment in this non-profit organisation. Also there is a threat in the negligence of smart/inventive logistical solutions as load on top and dedicated transport. When the barge owner/charterer is not financial responsible, logistical solutions will more expensive and controlled degassing is the most obvious action to execute. This will lead to more controlled degassing, which will lead to more capital investment in degassing units, which makes this scenario less feasible.

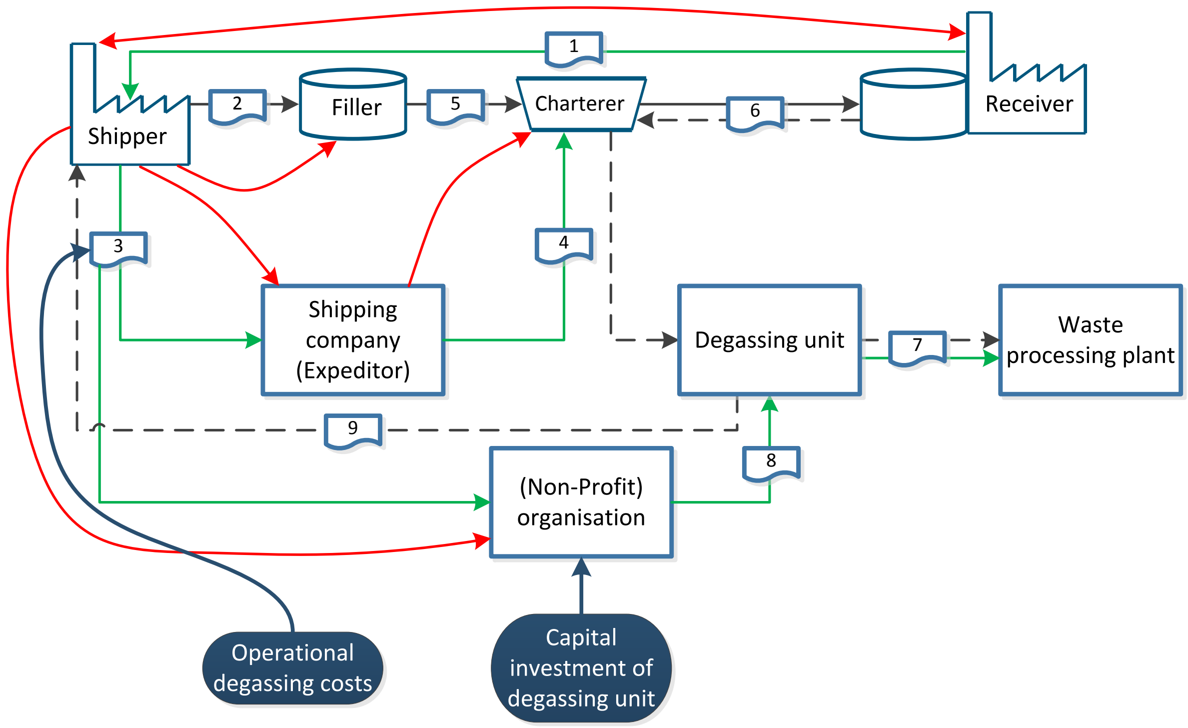

Figure 27: Supply chain design scenario 2

6.3.3 Cost estimate for degassing installations

Based on the average cost of ownership of all available degassing installations, specified in operational costs (opex) and capital/investment costs (capex), a cost estimate is created by comparing the average costs with the total required amount of degassing installations. The total amount of required degassing installation, based on 730 degassed barges per installation per year, as specified in figure 22 is used. The average costs of placement and ownership per degassing installation are estimated to be, operational costs: € 1.016.030 and capital investment costs (for placement of the installation) of: 1.705.068 on yearly basis. Total costs per year based on the phased degassing prohibition are displayed in figure 28 below.

Estimated degasssing installation cost	2014	2015	2016	2017	2018	2019	2020
Average degassing installation operational cost (yearly)	€ -	€ 664.533	€ 1.329.066	€ 1.329.066	€ 1.993.599	€ 2.658.132	€ 3.322.665
Average degassingistallation capital cost (yearly)	€ -	€ 1.705.068	€ 1.705.068	€ -	€ 1.705.068	€ 1.705.068	€ 1.705.068
Total	**€ -**	**€ 2.369.601**	**€ 3.034.134**	**€ 1.329.066**	**€ 3.698.667**	**€ 4.363.200**	**€ 5.027.733**

Figure 28: Total costs per year of the required degassing installations based on the phased degassing prohibition

7. Inspiring other regions and platforms

7.1 Introduction

In this chapter all the possible extra functions which this feasibility study can contribute and how it can inspire other regions and platforms.

7.2 Inspiring other regions and platforms

During the full project cycle, several actions should be foreseen in order to inspire other regions:

- Create engagement of relevant stakeholders within the supply chain,
- Exemplify by the demonstration project, which stimulates the imagination of other stakeholders in other chemical regions;
- Enable (describe learned lessons, based on the demonstration project)

Another platform in which degassing is not a large issue is the deep-sea transport. When the degassing prohibition is successfully implemented in the inland tank transport sector it can function as an example for the deep-sea transport sector.

IV. Conclusions

8. Conclusions

8.1 Introduction

In this paragraph concludes all the previous feasibility aspects. The sub-conclusions and findings are summarized into a major conclusion which will form the base of the recommendations towards the feasibility of the phased direct degassing prohibition.

8.2 Research question and phased subsidiary questions

The final conclusion of this feasibility study is the answer to the research question, this research question is determined of six subsidiary questions which represent the feasibility aspects.

8.2.1 Research question

The research question states as following:
"Is it feasible to create a sustainable and profitable solution for the degassing of barges in which an optional controlled return of chemical feedstock and chemical vapor molecules from discharged barges are brought back into the supply chain to the chemical producers necessitates."

8.2.2 Phased subsidiary questions/ feasibility aspects

The research question can be further specified into six phases with accompanying subsidiary questions of the project:

Phase 1: Logistics, Barge transport and movement

- How is the transport/barge movement of chemical feedstock organised within supply chain, divided in fixed sailing routes and UN-code specific.

Phase 2: Operations and substantively aspects

- Which options are available for the degassing of barges and which option(s) are the 'best' for the degassing of barges, based on set criteria.

Phase 3: Active stakeholders and laws & legislation

- Which stakeholders, laws and legislation have a role in executing this feasibility study and on which manner do they affect this feasibility study.

Phase 4: Risk setting/appointing

- Which risks are a major risks within the prohibition of degassing barges and for which parties are these risks applicable.

Phase 5: Financial aspects and profitability

- Which financial scenarios can be developed and how can these scenarios be executed.

Phase 6: Inspiring other regions and platforms

- How can this model be used for others substitutes and potential stakeholders

8.3 Final conclusions

Although the phases have much cohesion with each other on different levels, the phases are addressed separately in this final conclusion. These outcomes form the feasibility of the phased degassing prohibition.

8.3.1 Phase 1: Logistics, Barge transport and movement

In this phase an overview of the supply chain is given with an identification of the relevant product streams. The relation of these product streams are then coupled to the degassing of these products. The prohibition of the degassing of barges must be executed within a period of seven years (2014 – 2020). It is key that the phased prohibition is performed as gradually as possible divided over these seven years, therefore a prognosed phased degassing prohibition is introduced based on the physical traits of the substances and the amount transported in comparison with the total transported substances.

Multiple conclusions can be drawn from the transport flows, knowing the reason for direct degassing plays a large part in determining the feasibility of a phased prohibition. Because of quality requirements and the uncertainty of the knowledge of a next possible load, the market for charterers becomes more competitive and barge owners tend to be as flexible as possible. This has as consequence that the barge owner will degas as soon as possible to not be obstructed by these demands. In cases there might be a compatible load as next load and the degassing of the barge is unnecessary. The most common reason for direct degassing from a charterer's perspective is the lack of a vapour recovery systems on the land side which can be used. This is related to the high jetty occupation of terminals. Mostly terminals use their VRU-systems for their own processes (dedicated use). This is more from the view of a charterers perspective, which gives a one sided perspective. When comparing perspectives from all competing actors within the supply chain concerning the degassing of barges, an observation is that the directing role of the supply chain is in the hands of the shippers and expeditors. The barge/fleet owners are in a reactive role in this situation this is creates a lack of insight form the barge/fleet owners perspective. The cause of this lack in insight has to do with the load of barges which continuously switches of owner within the supply chain. The reason for this is because the product can be traded several times when moving through the supply chain. Due to this complicated ownership of freight within the supply chain, it is unclear which actor is eventually responsible for the residual after unloading the product. This makes the barge owner responsible for the degassing of barges and makes them responsible for the corresponding costs and loss of time. Additional, when a barge/fleet (owner) is chartered for a certain transport and charges an all-in tariff per hour for the transport which is executed. The time estimated for degassing of the barge is taking into account and added up with the total required transport time, which will form together the total charged time. This will create a lower threshold for direct degassing, because in this manner direct degassing has no direct effect on the cost effectiveness and is not considered as 'lost' time. In some cases barges will even take a detour for the purpose of degassing. This has a high cohesion with the low demand of inland tank transport and the high number of barges available, which is linked and further elaborated in the second phase.

8.3.2 Phase 2: Operations and substantively aspects

In this phase an overview of the different techniques for the degassing of barges is given. When all the techniques are described, they will be assessed on a set criteria , which give the most insight about the feasibility of the specific technique. The techniques where assessed with on a set criteria which are reviewed and then the balance scorecard principle is used to rank the various techniques, including direct external factors which are formulated by a SWOT-analysis. The higher scored techniques are: The load on top principle (compatibility list), dedicated transportation, incineration, direct degassing, membrane filtration and adsorption (with regenerative use of activated carbon). Direct degassing scored fairly high because of the easy operational use, nonetheless it will be prohibited so it is taken into account as a benchmark for the other techniques, which gives the other techniques a more validation form this point of view. It is important that the criteria are seen in a realistic perspective, for instance the applicability of techniques based on the variation substances which can be processed can play a role in the eventual choice for certain techniques. When taking the phased prohibition of direct degassing into account, the prohibition states on short-term the ban of the degassing of benzene and highly benzene containing products. When the relevant technique cannot cope with these substances it is less suitable for short-term but maybe useful for different product streams on long term. In this way the criteria are seen in a realistic perspective and are more validated. This is also the case for the ranking of 'sustainability' which can be interpreted on different levels. For instance for dedicated transport lies the environmental emissions in the extra covered distance and using fuel for it. The environmental emission for incineration are the added fuel for the incineration process, whether for other techniques the environmental emissions are measured in the use of power or the use of other additives within the process.

The largest effect of the first phase on the second phase is the low demand of inland tank transport, the barges do not have a direct consecutively order. Due to this unused time it is more likely to degas at the highest cost-effectiveness, instead of taking sustainability or duration into account, which in most cases leads to direct degassing. When the demand of inland tank transport increases the barge(fleet)owners will experience more importance in for instance the duration of degassing, which will eventually help developing the gas-processing techniques for mutual benefit. The techniques which are in testing phase are all very promising in theory. What these techniques require are tests from which they can learn and adjust their technique and eventually reach the level of an operational usable technique to degas inland barges. However the entire market with all its actors of inland barge transport are waiting for the most suitable technique to be fit for their use and the technique suppliers are waiting of reaction and interaction of the market. Due to this construction the development of techniques improves slowly. From various expert judgments form the field of suppliers of degassing techniques and interviews with relevant stakeholders, the emphasis of the working efficiency of techniques is focused on the last remaining VOC-vapours. In the experience of gas processing units one could say 20% of the last remaining VOC-vapours is 80% of the total effort within the total degassing process. This problem has a high cohesion with the lack of clear legislation of a level of 'gas free', this has the cause that vapour levels are measured in various standards with different starting-points, which is further specified in the Active stakeholders and laws & legislation phase.

8.3.3 Phase 3: Active stakeholders and laws & legislation

In this phase the laws and legislation are described on an international level, national level and a local level. In addition an active stakeholder analysis was created which displays all parties within the scope of the degassing of inland tank vessels. The playing field concerning the degassing of inland barges is very complicated. There are many parties with in some cases mixed interests. This can have negative consequences for the collaboration and transparency between parties within the supply chain. The cohesion between the first two phases and the third phase is very large. This is clearly shown form an operational point of view in the fact that there is no regulation of the active direct degassing prohibitions in Germany. Nevertheless the barge(fleet)owners postpone the direct degassing within the German waterways and start direct degassing when passing the border and reaching The Netherlands or other countries which have a less strict direct degassing prohibition. This creates a flow of liquid free vessels which need to be degassed, this can be described as 'direct degassing tourism' which takes place.

From the technical point of view there is a high cohesion concerning the lack of clear legislation of a level of 'gas free'. Due to the different levels of laws and legislation and different perspectives/purposes of the interpretation of degassing it is unclear about when a vessel can be declared 'Degassed'. The standard which is used are the standards described in the ADN, which is the level of <10% of the lowest explosion limit (LEL), this legislation is from a safety point of view. This differs from an environmental point of view and must be seen in separate perspective. An environmental point of view are stated in the NER (The Dutch emissions guidelines) and the WABO (The General Provisions of Environmental Law). Additional there is lack of clear laws and legislations to which a floating degassing installation (placed on a pontoon) must suffice. This lack creates not only a unclear perspective about the level of degassing, but also an unclear perspective of the technical, safety and environmental demands to which a floating degassing installation must suffice. This makes the task of the provider of the relevant degassing techniques to create a suitable platform for a applicable degassing technique more complicated. This creates a less suitable position for floating degassing techniques and sets more pressure on shore based degassing options which has the problem of already too high jetty occupation. This slows the development of techniques down and clearly shows the cohesion between, operational, technical and legislation related feasibility.

A vital element within the re-use of chemicals principle is the degassing as a physical operation, which needs to be seen as a disconnected part from the unloading procedure. However, degassing is an aspect of the total physical distribution as such. The responsibility for the correct execution of the degassing and the delivery of the degassed cargo tanks therefor needs to be specified in which parties are responsible for which operation within the supply chain. The shared responsibility of parties in the supply chain needs to be worked out in a detailed level, taking into account the need of collaboration, transparency and market uniformity in the supply chain, before legal obligations and regulated laws and legislation can be introduced. To realise an effective re-use of chemicals the current laws and legislation must be in line with the operational re-use of chemicals. An essential aspect concerns the qualification of the cargo vapours, respectively the liquefied gaseous residues in terms of waste treatment. Liquefied vapours and gasses from previous cargos should therefore not be defined as waste. In this order the respective volumes could be reintegrated in the supply chain. The procedures and reglementary framework should be in line with the re-use of chemicals principle.

8.3.4 Phase 4: Risk setting/appointing

In this phase all the risks are appointed within the supply chain concerning degassing in the frame of a risk analysis model. Which specific risk model was used and what drives these risks will be analysed. The input for this chapter are the conclusions which are drawn in the previous chapters. The research goal was to develop a model to assess risks in the supply chain and to involve the AHP method in the definition of decision priorities. The model will create awareness of supply chain risk factors within the feasibility of implementing the phased prohibition direct degassing of inland tank vessels. This is done by establishing a thorough consideration of critical issues and interdependencies in determining a complete risk analysis. The conclusion which can be drawn from the risk-analysis is in line with the previous conclusion of the previous executed research phases. Through the risk landscape it becomes visible that the highest risks lie in the law & legislation feasibility and in the operational feasibility. The most severe risks within the supply chain lie within the charterers area. This is the area with the least insight within the supply chain. Additional the charterers, (barge/fleet)owners hold the physical problem (the residual vapours), this creates the highest risks.

The operational, technical and legislation feasibility have a high cohesion with each other, mostly in form of a cause-effect relation. This makes the supply chain concerning the prohibition of direct degassing very complicated. Form the conclusions which are strengthened in visibility, insight and cohesion of risks within the supply chain by the risk-analysis. Two scenarios are developed in the 'Financial aspects and profitability' phase taking into account the risks which are appointed.

8.3.5 Phase 5: Financial aspects and profitability

In this phase will be described which financial scenarios within supply chain designs can be developed and how these scenarios can be executed, taking into account the risks which are formulated in the previous phase.

The scenarios which are formulated are based on the prohibition of direct degassing and are therefore more sustainable designed supply chain scenarios which support to implement a well working financial structure within all stakeholders in the supply chain. The key to the most feasible scenario is to intervene as little as possible within the existing supply chain. The direct impact of this in this scenario is that direct degassing is no longer possible, this creates a situation that when degassing is necessary the charterer must perform a form of controlled degassing. This makes the content of the contracts which are specified more important. The responsibility of the residual vapour in the barge must be appointed to a party in the supply chain in form of contracts and thereby the costs for degassing must be appointed based on contracts which can be handed over. In this case the responsibility and liability within the supply chain cannot be evaded through contracts. In this manner the supply chain becomes more transparent and can solve the additional costs of controlled degassing by calculating the extra costs of controlled degassing in their margins through the entire supply chain. The most likely effect of this scenario can be best elaborated by following the financial flow displayed in the figure in the other direction to which the financial streams flow. The charterer finances the degassing costs, due to this finance the margins of the charterer increases. Due to this increase of demanding price the price raises with a certain margin throughout the entire supply chain. This eventually results to a minimum increase of the margin of the final product at the end of the supply chain. Taking into account in this scenario is the re-use of the vapours, when the promising techniques with the re-use of chemicals are operational, an agreement can take place between the charterer and the shipper to make use of the recovered product. This must also be registered as transparent as possible via contracts which can be handed over. In this manner the responsibility of the vapours is registrated and it does not matter when it is traded several times within the supply chain. When the product cannot be recovered it can be controlled degassed (and destroyed) directly or the recovered product can be processed and destroyed at a waste processing plant. Through this scenario the investment/capital costs are not focused on one actor in the supply chain, this has an advantage in implementing. The degassing units are not funded by external, municipalities, overarching or additional branch parties concerning the degassing problem. An possible advantage is that this scenario will solve the degassing issue quick and as efficient as possible because everyone in the supply chain is direct financial involved in the compliance of the prohibition. This will has as consequence that the entire responsibility of product, information and financial flows of supply chain stakeholders is shared. However the overarching parties such as the Port of Rotterdam and municipalities should regulate that the amount of existing gas processing units match the required gas processing units which are in line with the estimated demand of barges which need to be degassed. By letting the costs of degassing be divided over the entire supply chain, parties will take actions to reach forms of supply chain collaboration to reduce their costs, in this manner the entire 'degassing problem' will solve itself partially.

The sixth phase is has no direct influence on the final conclusion, this phase has the function to exemplify as demonstration project, which stimulates the imagination of other stakeholders in other chemical regions.

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10. Appendices

Appendix 1: Products unloaded (IVS 90 Database)

UN code	Name	Transported weight (ton)	Number of shipping movements	Unloaded in Netherlands (ton)	Unloaded outside Netherlands (ton)	Unloaded in Rotterdam (ton)	Unloaded in The Netherlands excl. Rotterdam (ton)
1090	Acetone	321266	199	180774	140492	154349	26425
1093	Acrylonitrile, stabilized	78281	67	31470	46811	4165	27305
1114	Benzene/ pygas/reformate >10% benzene	1502538	925	738973	763564	269509	469464
1120	Butanols	138376	126	64245	74131	60844	3401
1145	Cyclohexane	397521	351	4220	393301	1320	2900
1170	Ethyl Alcohol	723563	657	201170	522393	81946	119224
1173	Ethyl acetate	9454	10	3490	5964	1499	1991
1175	Ethyl benzene	298796	127	292511	6285	2600	289911
1179	Ethyl butyl ether	123090	105	7804	115286	1975	5829
1184	Ethylene dichloride	125736	99	92445	33291	2529	89916
1193	Methyl ethyl ketone	5600	7	2950	2650	2000	950
1203	Gasoline	5723837	3377	3708394	2015443	447301	3261093
1206	Heptanes	11711	11	550	11161	550	0
1208	Hexanes	4556	6	4136	420	3036	1100
1213	Isobutyl acetate	5939	6	983	4956		983
1216	Iso octenes	138895	110	7236	131659	6631	605
1219	Isopropyl alcohol	20578	27	8178	12400	6002	2176
1220	Isopropyl acetate	399	1	399			399
1230	Methanol	2014398	1518	141653	1872745	85613	56040
1265	Pentanes (all isomers)	8276	5	4537	3739	1537	3000
1268	Petroleum products N.O.S. (Distillates)	9202032	4669	4918153	4283879	1754342	3163811
1280	Propylene oxide	406170	294	130384	275786	3700	126684
1294	Toluene	119431	100	52413	67018	36499	15914
1300	Turpentine substitute	47424	36	46024	1400	43476	2548
1301	Vinyl Acetate, stabilized	51353	62	9835	41518	9335	500
1307	Xylenes/ethylbenzene (10% or more) mixture	717159	481	234915	482244	191082	43833
1547	Aniline	102210	76	17957	84253	12821	5136
1662	Nitrobenzene	100780	88	76342	24438	60241	16101
1863	Jet fuel	3975637	1574	1952092	2023545	142734	1809358
1918	Isopropylbenzene	322810	147	38107	284703	2625	35482
1993	Flammable liquid N.O.S.	356046	408	148740	207306	38363	110377
2048	Dicyclopentadiene	7628	13	1060	6568	510	550
2055	Styrene Monomer, stabilized	1135801	913	427893	707908	41020	386873
2312	Phenol, molten	121810	67	89222	32588	72467	16755
2398	Methyl-tert-Butylether	791755	598	615166	176588	355578	259588
2491	Ethanolamine	600	1	600			600
2789	Glacid acid	335353	291	85013	250340	26111	58902
3092	1-Methoxy-2-propanol	52750	67	3957	48793	500	3457
3272	Esters, N.O.S. (Propylene glycol methyl ether	24783	24	21982	2801	20339	1643
3295	Hydrocarbons, liquid N.O.S.	3823088	195	2691357	1131730	427933	2263424
3463	Propionic acid with not less than 90% acid by	5064	9	660	4404		660
Total		**33494510**	**17847**	**17089928**	**16404582**	**4395819**	**12694109**

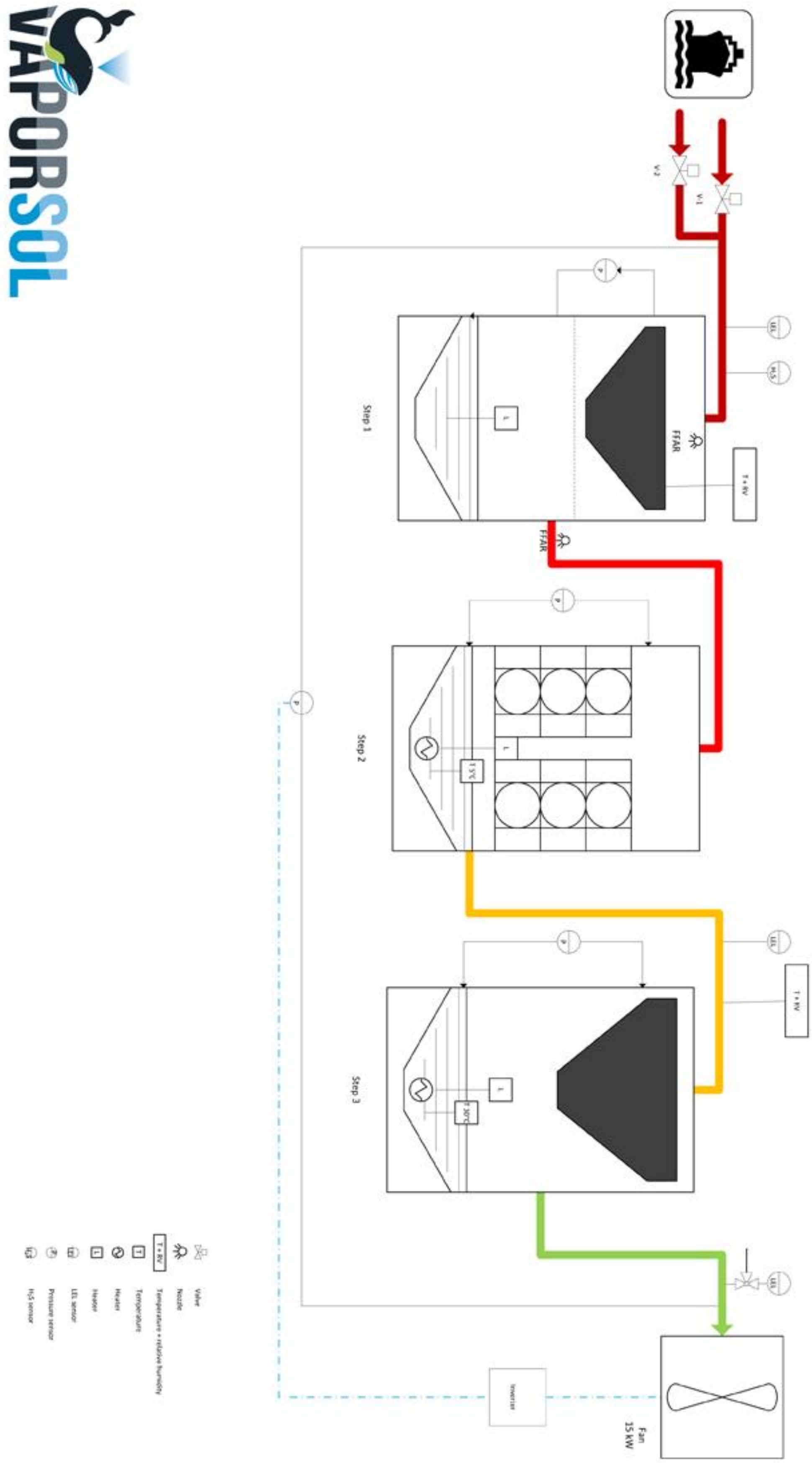
Appendix 2: percentages of degassed products

UN code	Name	Next load identical	Next load compatible	100% dedicated ships	% degassed
1090	Acetone	61%	N.A.	0%	39%
1093	Acrylonitrile, stabilized	39%	N.A.	0%	0%
1114	Benzene/ pygas/reformate >10% benzene	54%	N.A.	0%	46%
1120	Butanols	10%	N.A.	0%	90%
1145	Cyclohexane	95%	N.A.	0%	5%
1170	Ethyl Alcohol	32%	N.A.	0%	68%
1173	Ethyl acetate	0%	N.A.	0%	100%
1175	Ethyl benzene	33%	N.A.	0%	67%
1179	Ethyl butyl ether	0%	N.A.	0%	100%
1184	Ethylene dichloride	84%	N.A.	0%	16%
1193	Methyl ethyl ketone	0%	N.A.	0%	100%
1203	Gasoline	62%	30%	5%	0%
1206	Heptanes	0%	N.A.	0%	100%
1208	Hexanes	0%	N.A.	0%	100%
1213	Isobutyl acetate	0%	N.A.	0%	100%
1216	Iso octenes	90%	N.A.	90%	10%
1219	Isopropyl alcohol	0%	N.A.	0%	100%
1220	Isopropyl acetate	0%	N.A.	0%	100%
1230	Methanol	76%	N.A.	2%	0%
1265	Pentanes (all isomers)	0%	N.A.	0%	100%
1268	Petroleum products N.O.S. (Distillates)	43%	36%	6%	28%
1280	Propylene oxide	96%	N.A.	96%	0%
1294	Toluene	26%	N.A.	0%	74%
1300	Turpentine substitute	15%	N.A.	0%	85%
1301	Vinyl Acetate, stabilized	42%	N.A.	0%	58%
1307	Xylenes/ethylbenzene (10% or more) mixture	30%	N.A.	0%	70%
1547	Aniline	27%	N.A.	0%	0%
1662	Nitrobenzene	63%	N.A.	0%	0%
1863	Jet fuel	94%	N.A.	34%	0%
1918	Isopropylbenzene	21%	N.A.	0%	79%
1993	Flammable liquid N.O.S.	53%	N.A.	5%	80%
2048	Dicyclopentadiene	100%	N.A.	0%	0%
2055	Styrene Monomer, stabilized	78%	N.A.	1%	22%
2312	Phenol, molten	81%	N.A.	13%	0%
2398	Methyl-tert-Butylether	16%	N.A.	0%	97%
2491	Ethanolamine	0%	N.A.	0%	100%
2789	Glacid acid	50%	N.A.	0%	50%
3092	1-Methoxy-2-propanol	0%	N.A.	0%	100%
3272	Esters, N.O.S. (Propylene glycol methyl ether acetate)	0%	N.A.	0%	100%
3295	Hydrocarbons, liquid N.O.S.	36%	N.A.	10%	85%
3463	Propionic acid with not less than 90% acid by mass	0%	N.A.	0%	100%
Total					

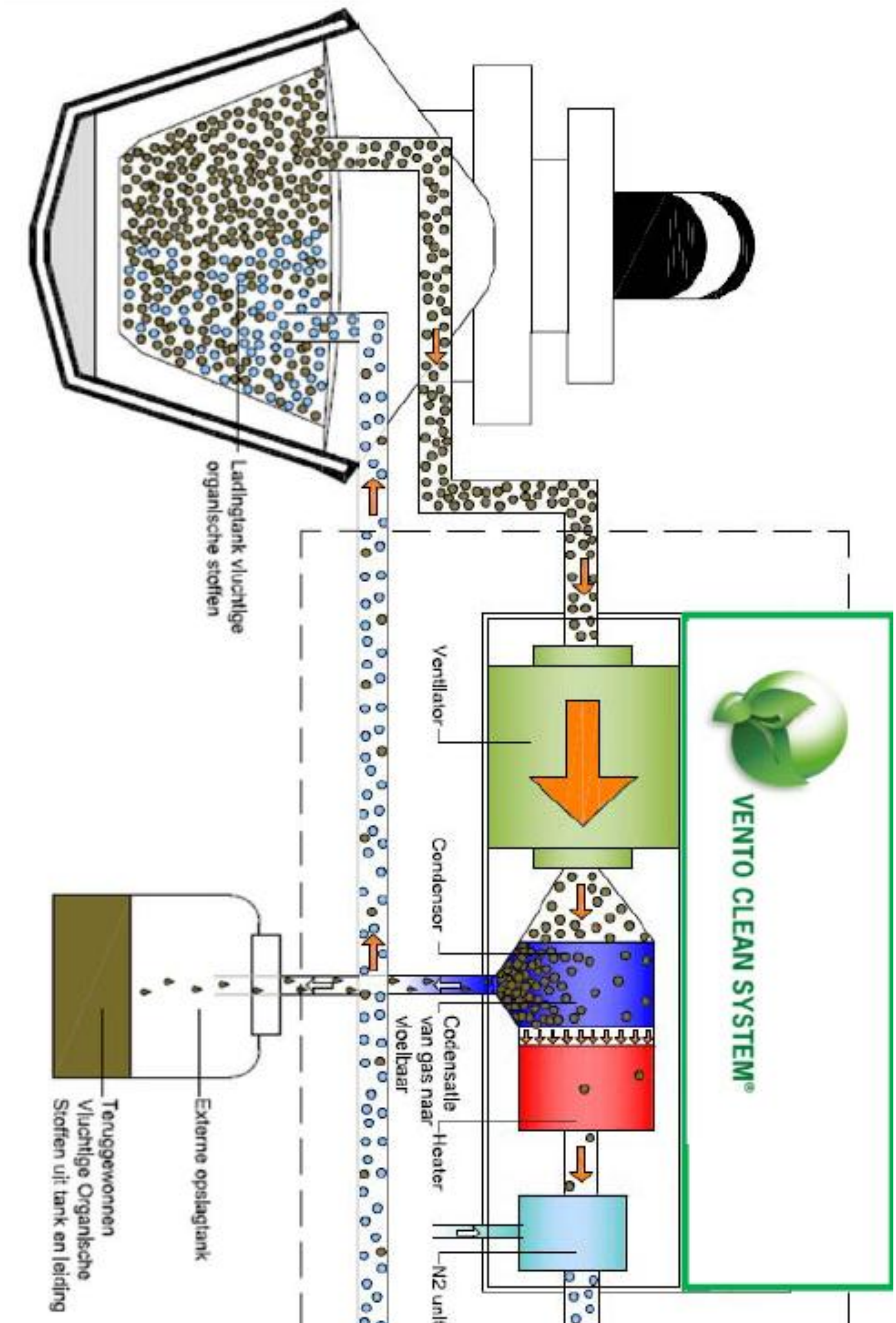
Appendix 3: product flow degassed barges

		Goods flow in (transport)				Number of degassings			
UN code	Name	Unloaded in Netherlands	Unloaded outside Netherlands	Unloaded in Rotterdam	Unloaded in The Netherlands excl. Rotterdam	Unloaded in Netherlands	Unloaded outside Netherlands	Unloaded in Rotterdam	Unloaded in The Netherlands excl. Rotterdam
1090	Acetone	112	87	96	16	44	34	29	5
1093	Acrylonitrile, stabilized	27	40	4	23	0	0	0	0
1114	Benzene/ pygas/reformate >10% benzene	455	470	166	289	210	216	79	138
1120	Butanols	58	68	55	3	53	61	58	3
1145	Cyclohexane	4	347	1	3	0	18	6	12
1170	Ethyl Alcohol	183	474	74	108	124	323	131	191
1173	Ethyl acetate	4	6	2	2	4	6	3	4
1175	Ethyl benzene	124	3	1	123	84	2	0	2
1179	Ethyl butyl ether	7	98	2	5	7	98	25	73
1184	Ethylene dichloride	73	26	2	71	12	4	0	4
1193	Methyl ethyl ketone	4	3	3	1	4	3	2	1
1203	Gasoline	2188	1189	264	1924	0	0	0	0
1206	Heptanes	1	10	1	0	1	10	10	0
1208	Hexanes	5	1	4	1	5	1	0	0
1213	Isobutyl acetate	1	5	0	1	1	5	0	5
1216	Iso octenes	6	104	5	0	1	10	10	1
1219	Isopropyl alcohol	11	16	8	3	11	16	12	4
1220	Isopropyl acetate	1	0	0	1	1	0	0	0
1230	Methanol	107	1411	65	42	0	0	0	0
1265	Pentanes (all isomers)	3	2	1	2	3	2	1	1
1268	Petroleum products N.O.S. (Distillates)	2495	2174	890	1605	699	609	217	392
1280	Propylene oxide	94	200	3	92	0	0	0	0
1294	Toluene	44	56	31	13	32	42	29	13
1300	Turpentine substitute	35	1	33	2	30	1	1	0
1301	Vinyl Acetate, stabilized	12	50	11	1	7	29	28	1
1307	Xylenes/ethylbenzene (10% or more) mixture	158	323	128	29	110	227	184	42
1547	Aniline	13	63	10	4	0	0	0	0
1662	Nitrobenzene	67	21	53	14	0	0	0	0
1863	Jet fuel	773	801	57	716	0	0	0	0
1918	Isopropylbenzene	17	130	1	16	14	103	7	96
1993	Flammable liquid N.O.S.	170	238	44	126	137	190	49	141
2048	Dicyclopentadiene	2	11	1	1	0	0	0	0
2055	Styrene Monomer, stabilized	344	569	33	311	76	125	12	113
2312	Phenol, molten	49	18	40	9	0	0	0	0
2398	Methyl-tert-Butylether	465	133	269	196	451	130	75	55
2491	Ethanolamine	1	0	0	1	1	0	0	0
2789	Glacid acid	74	217	23	51	37	109	33	76
3092	1-Methoxy-2-propanol	5	62	1	4	5	62	8	54
3272	Esters, N.O.S.	21	3	20	2	21	3	3	0
3295	Hydrocarbons, liquid N.O.S.	137	58	22	115	117	49	8	41
3463	Propionic acid with not less than 90% acid by mass	1	8	0	1	1	8	0	8
Total		**8349**	**9498**	**2419**	**5931**	**2302**	**2497**	**1020**	**1478**

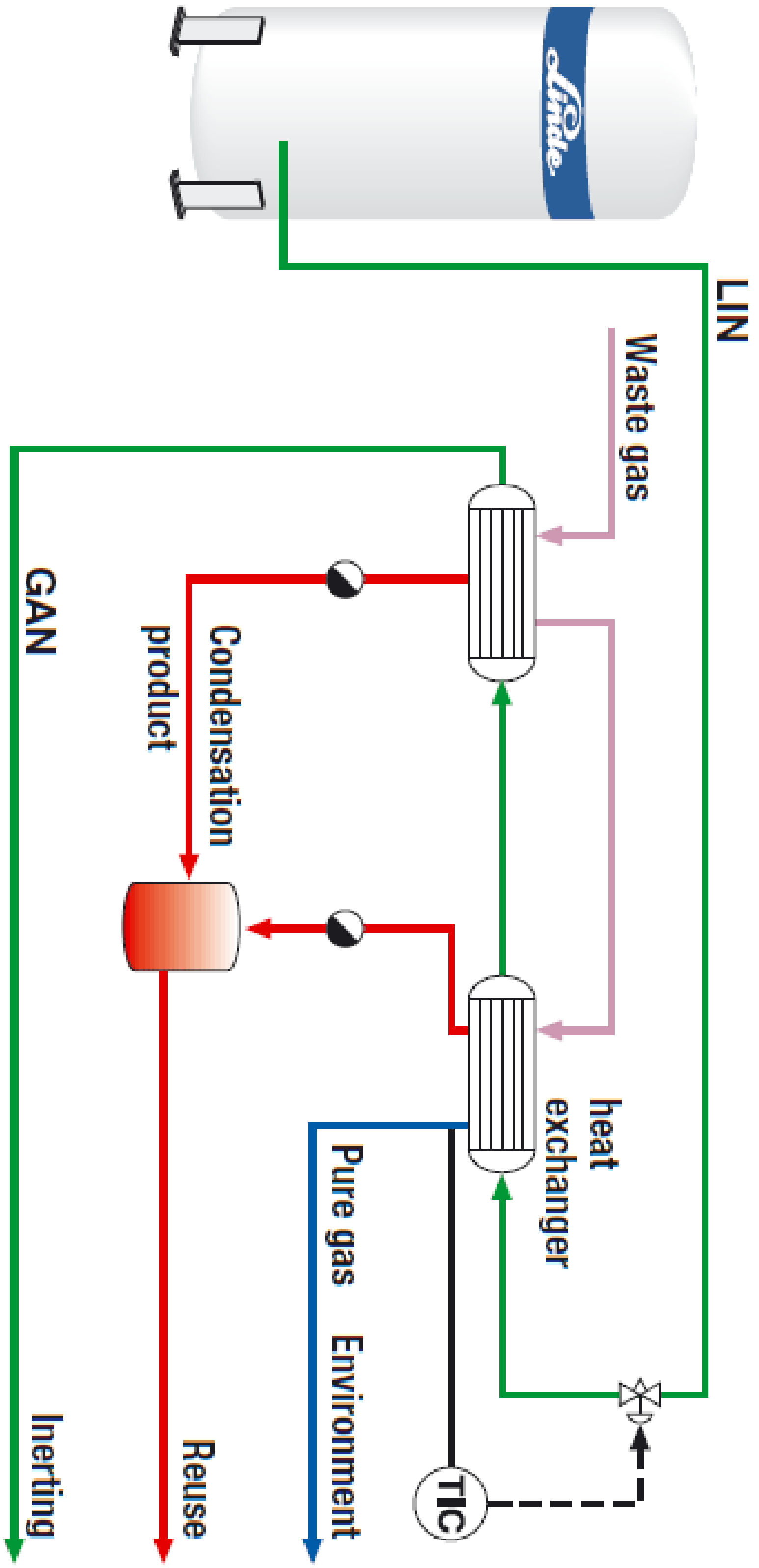
Appendix 4: Vaporsol schematic overview



Appendix 5: VentoClean-System schematic overview

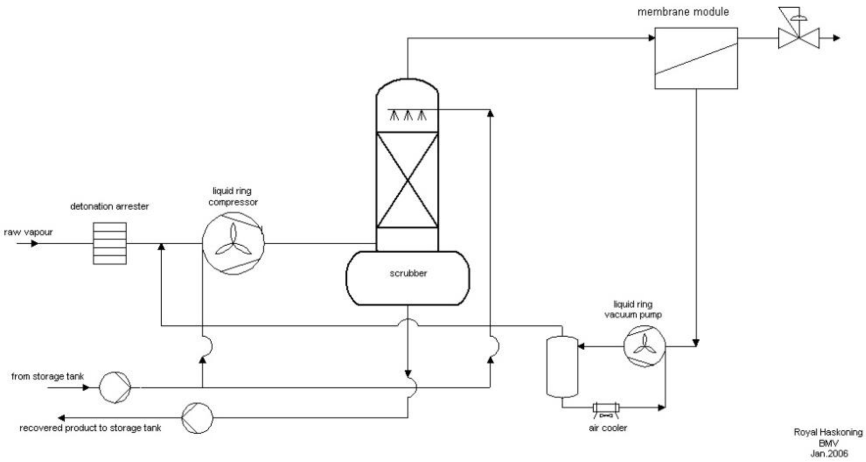


Appendix 6: Cryo-condensation AQ Linde schematic overview

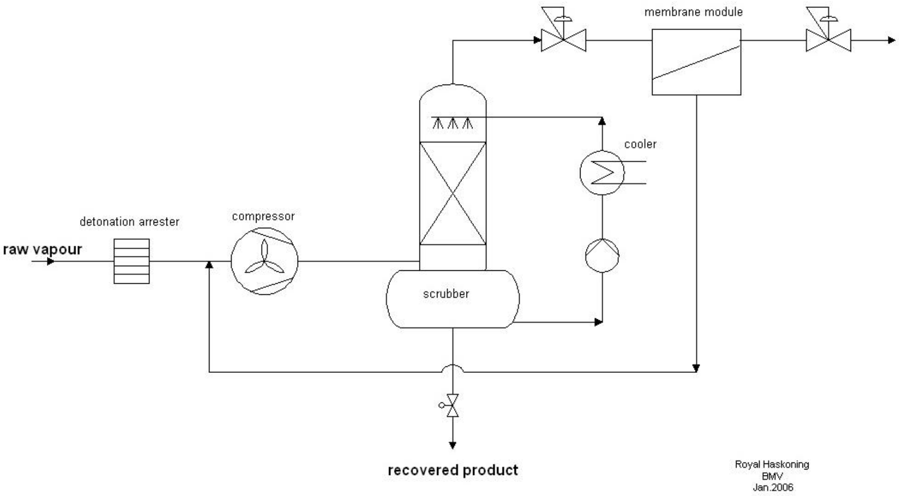


Appendix 7: Membrane filtration schematic overview

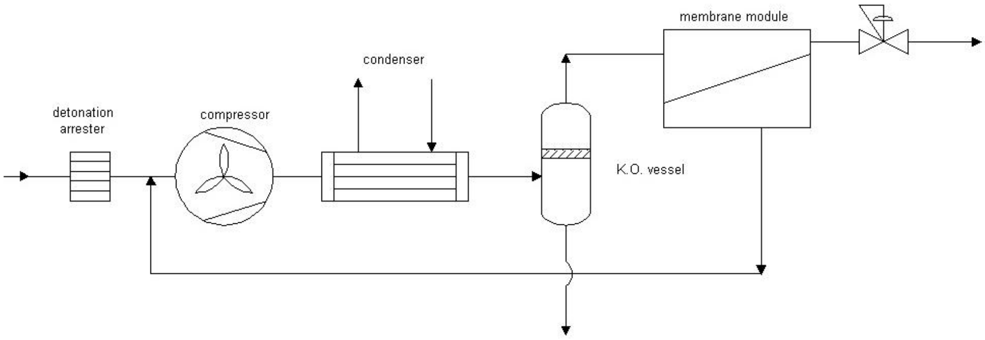
configuration 1



configuration 2



configuration 3



Appendix 8: Pressure swing adsorption

Fig.1. Pressure Swing Adsorption

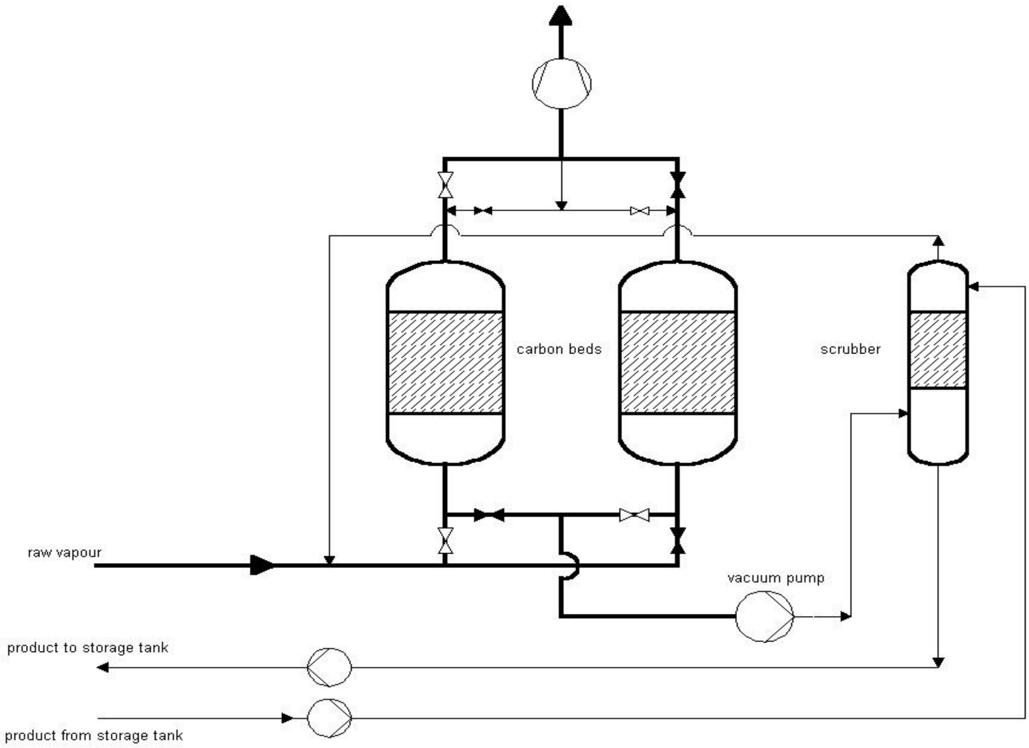
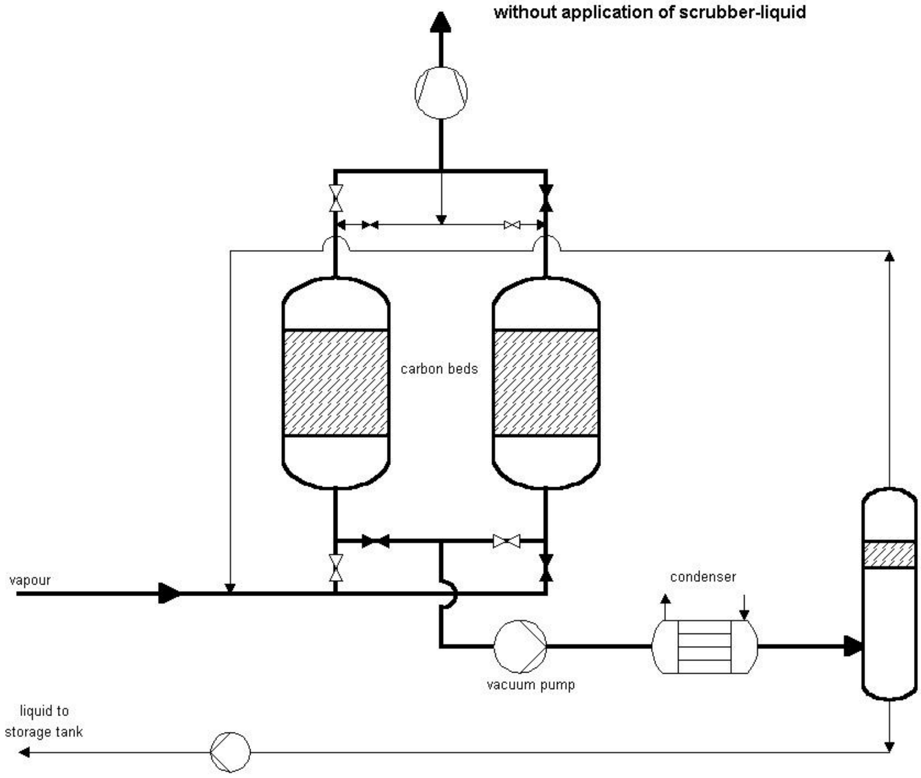
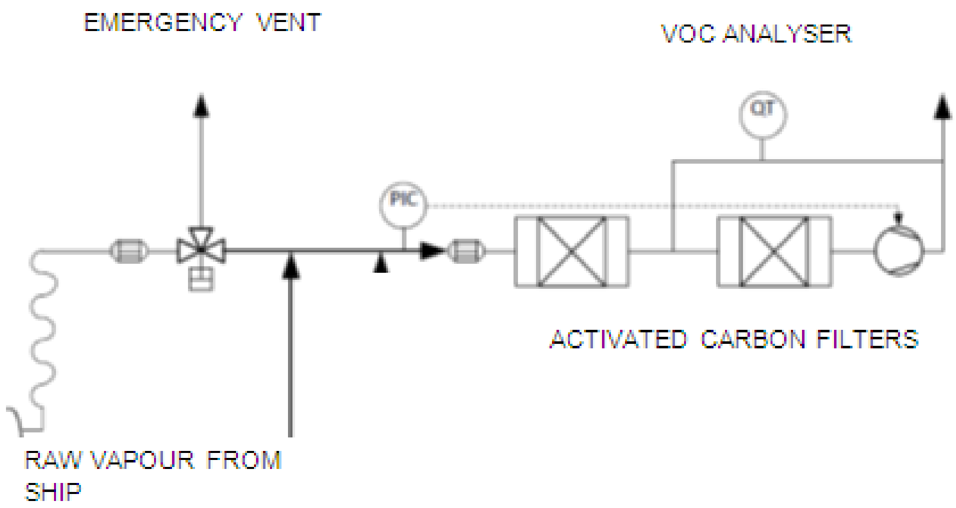


Fig.2. Pressure Swing Adsorption

without application of scrubber-liquid



Appendix 9: Adsorption with sacrificial filter beds schematic overview



Appendix 10: Incineration schematic overview

Figure 1. Pre-heating of the vapour flow

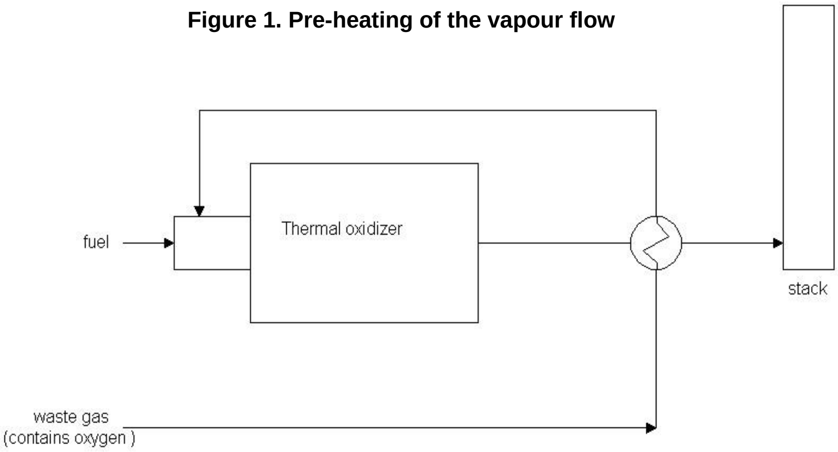


Fig. 2: Pre-heating of vapour flow and combustion air

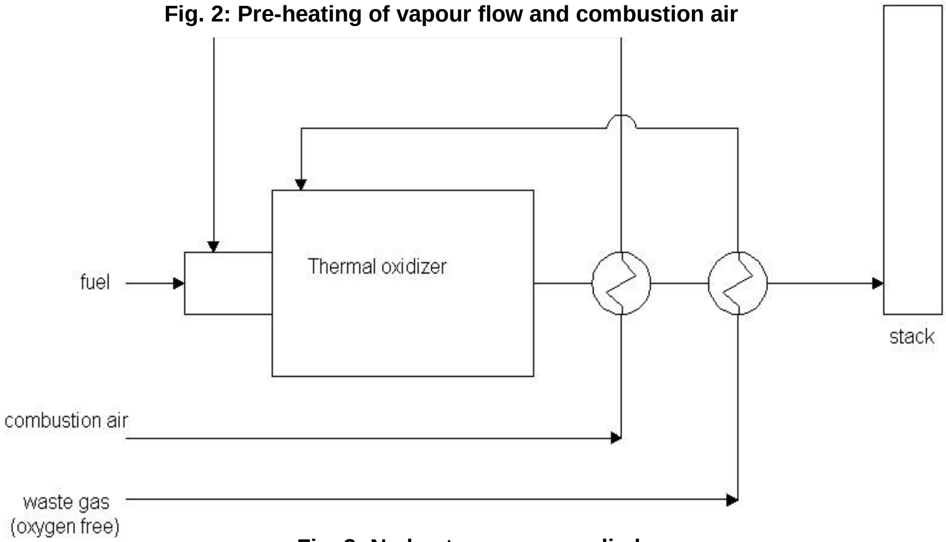
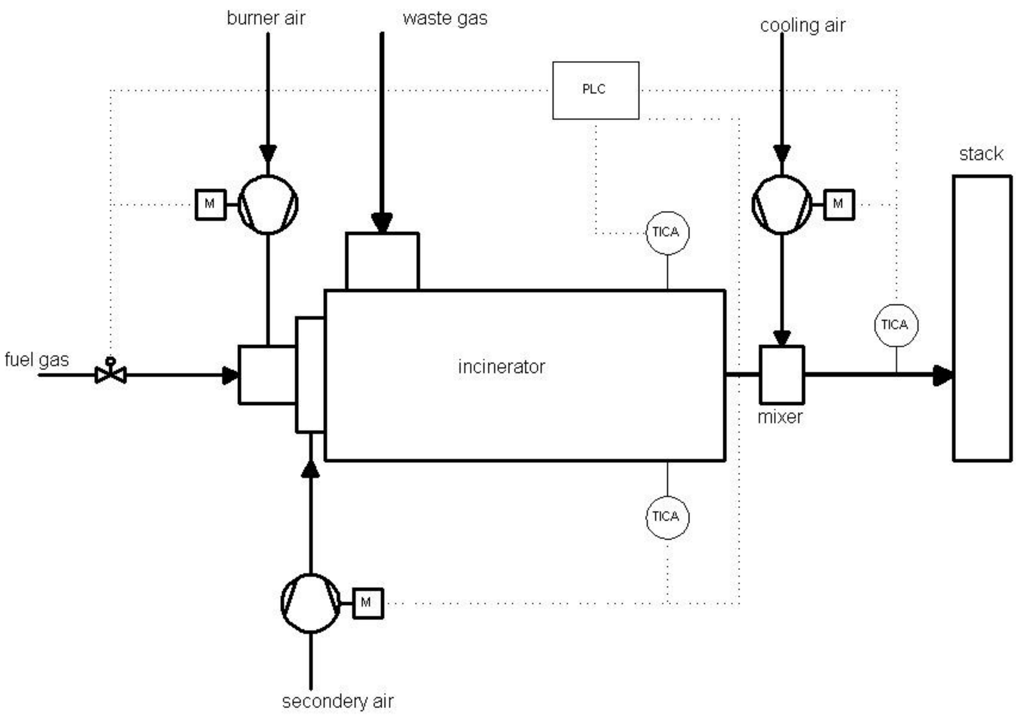
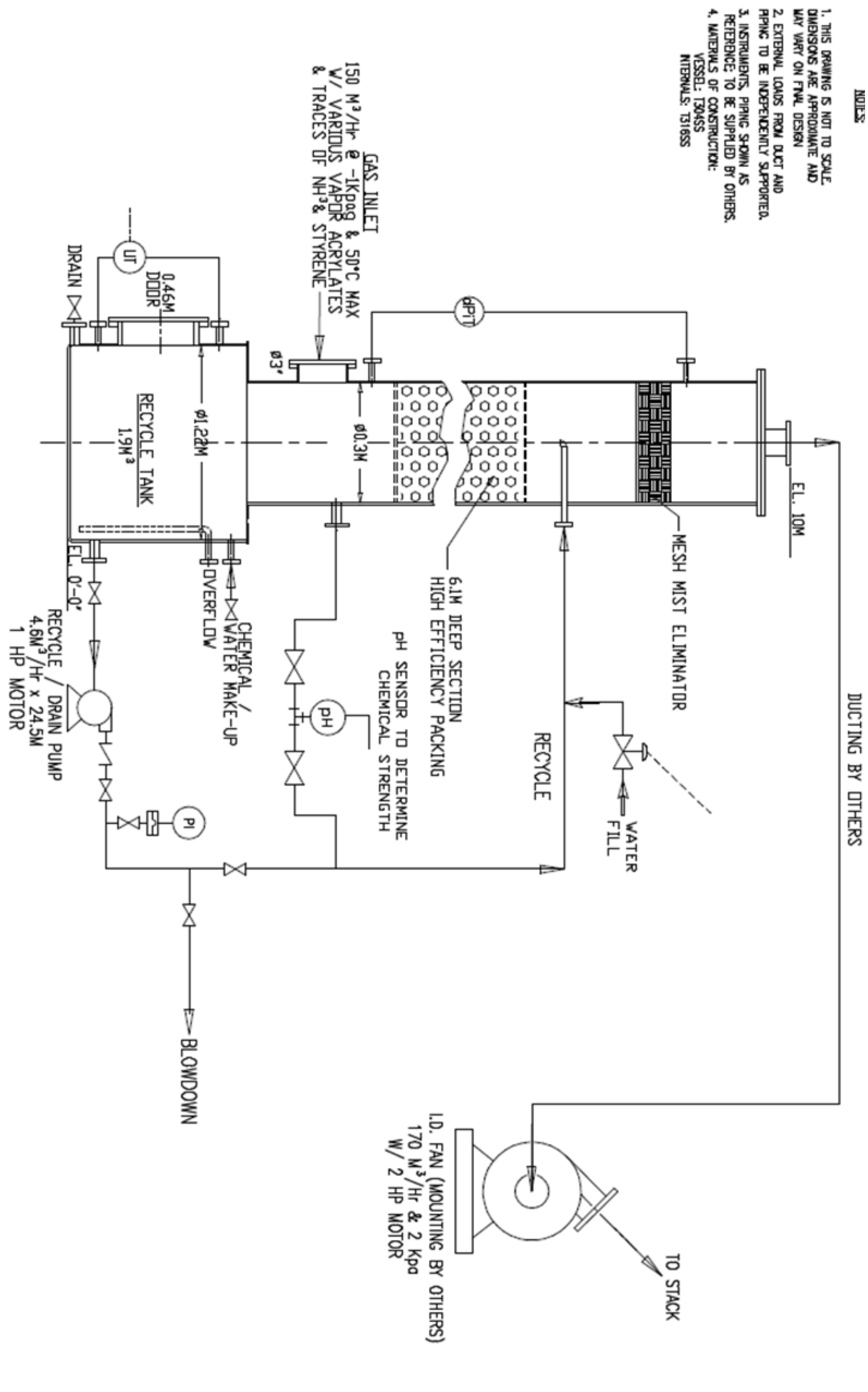


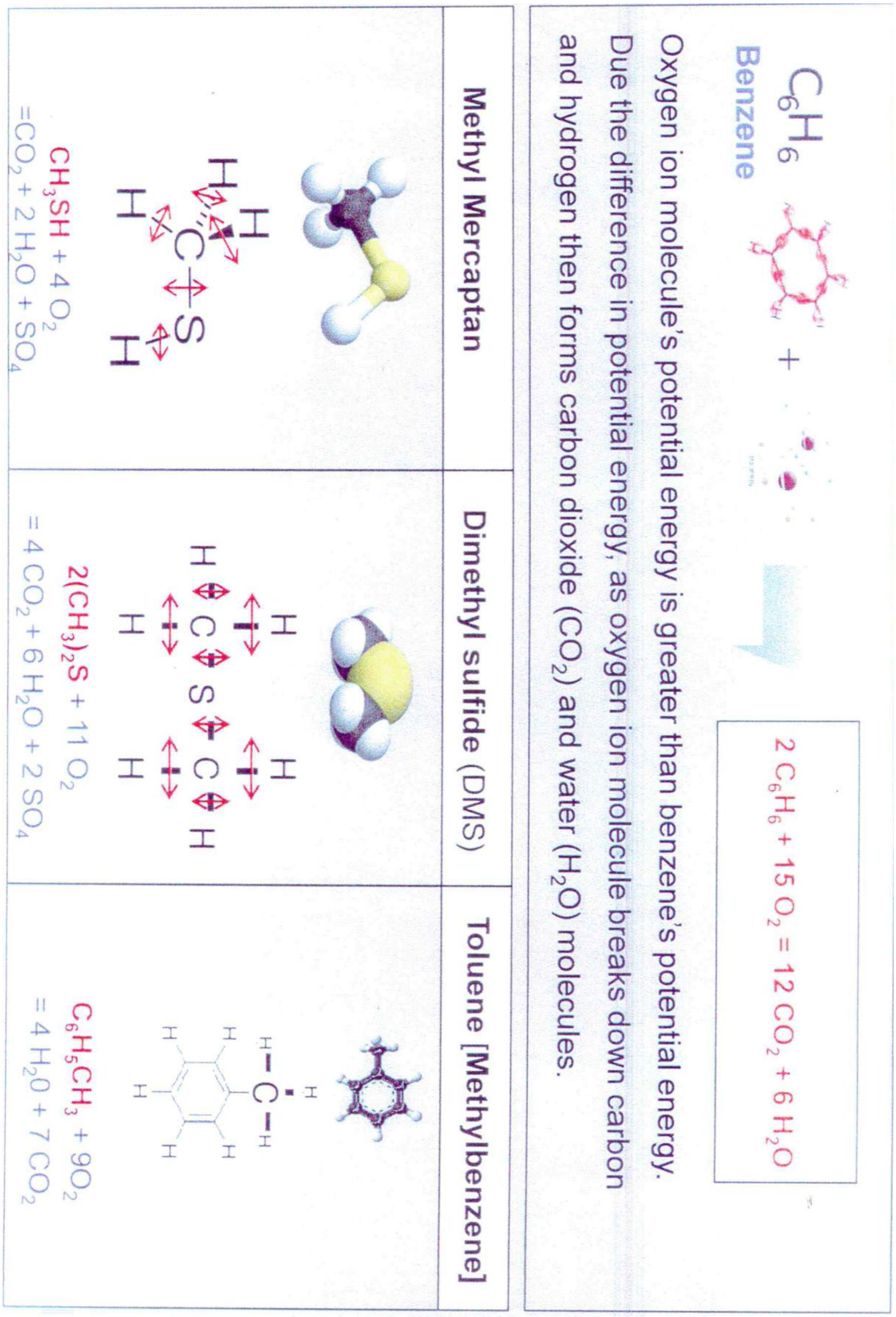
Fig. 3: No heat-recovery applied



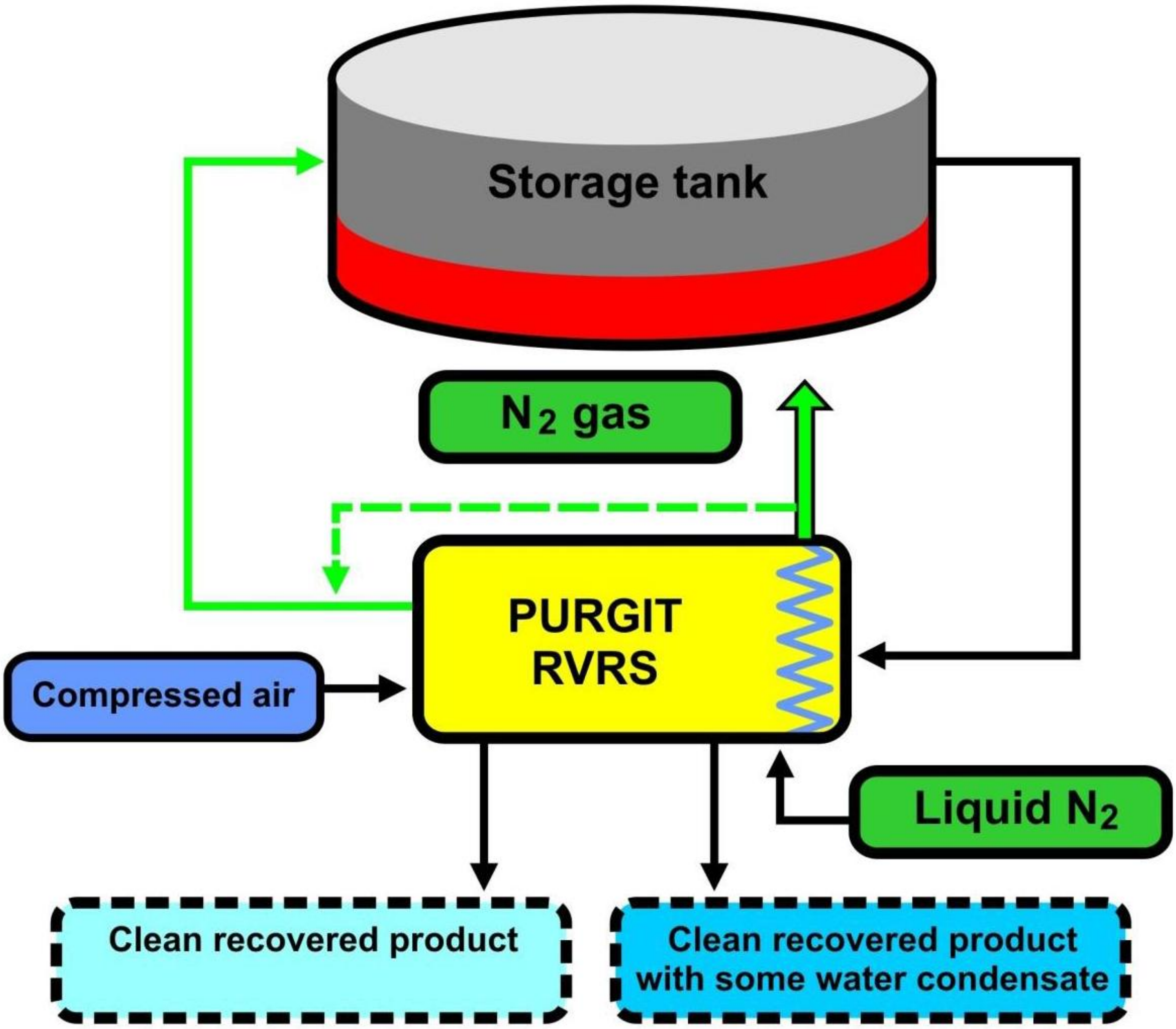
Appendix 11: Scrubbing schematic overview

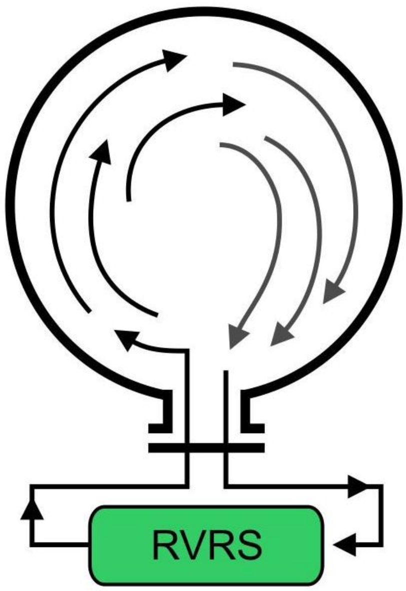


Appendix 12: Ion2Air schematic overview

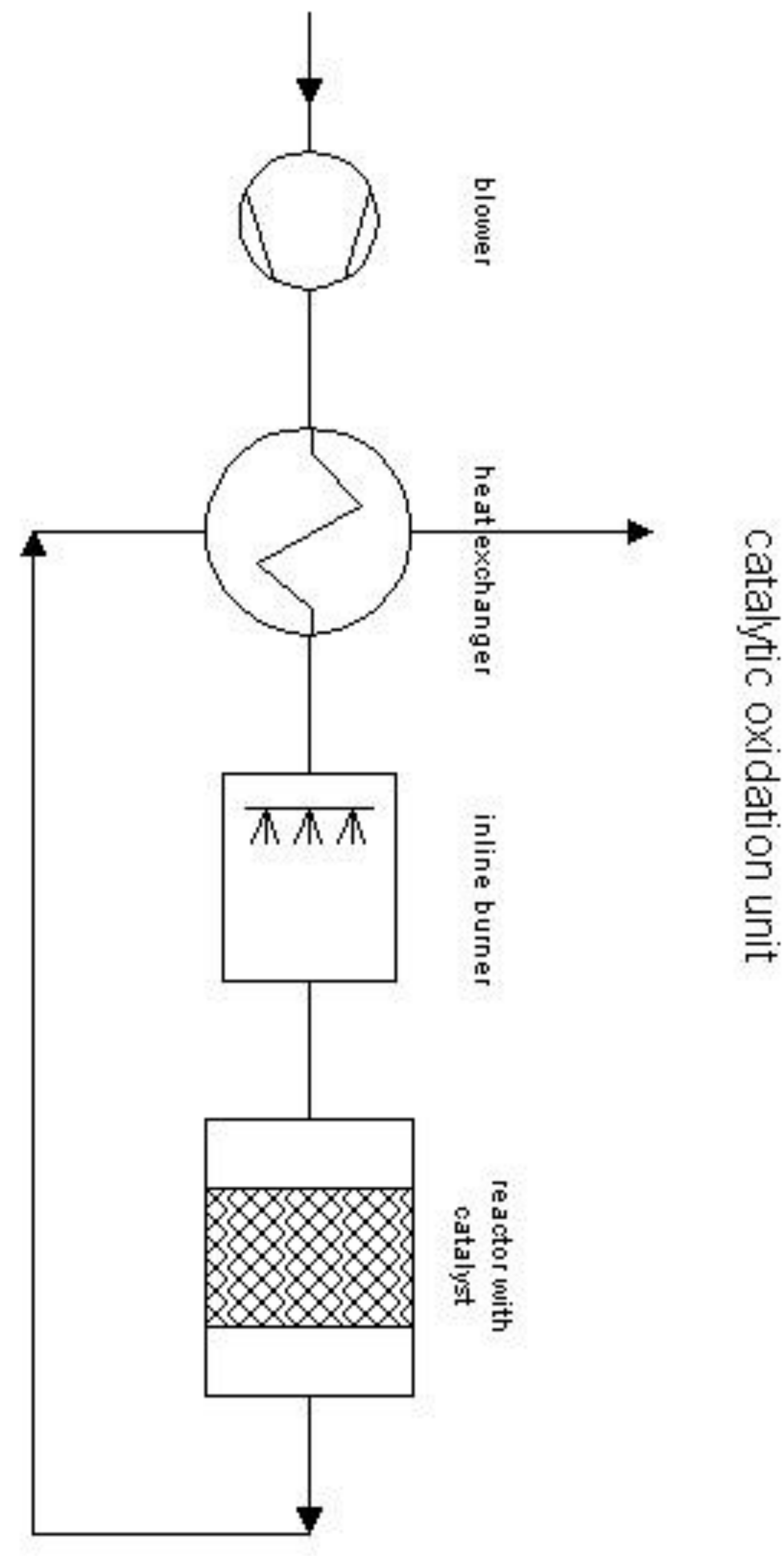


Appendix 13: Mariflex/purgit schematic overview

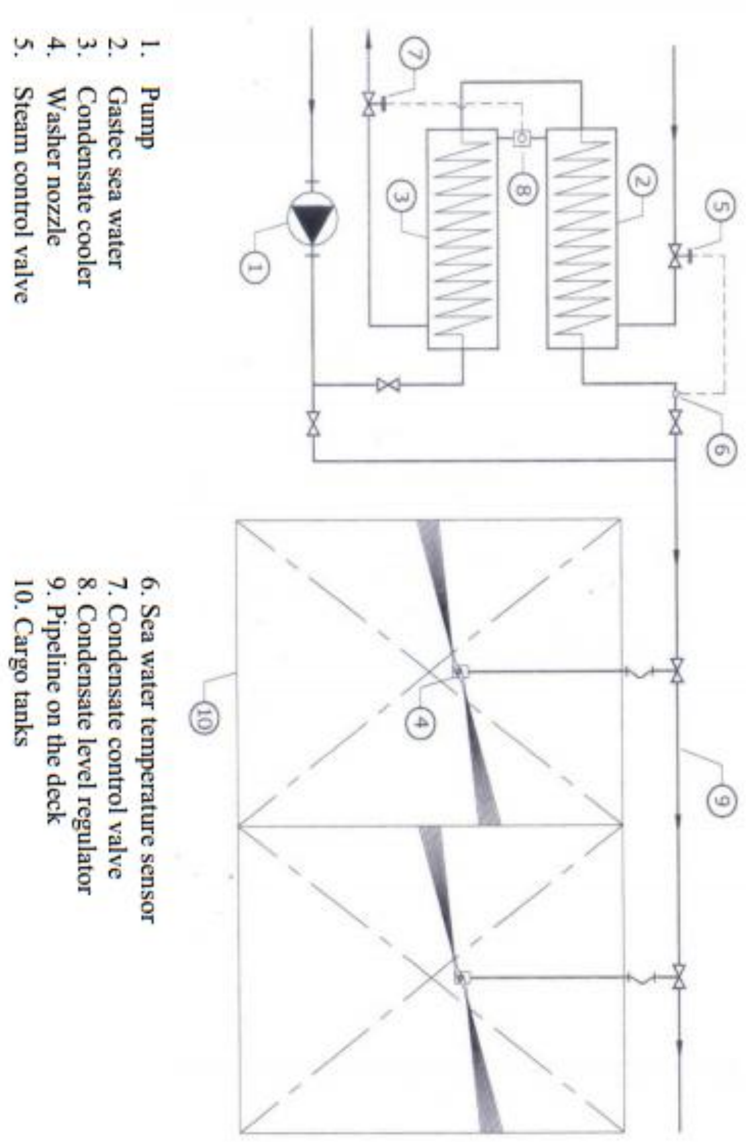




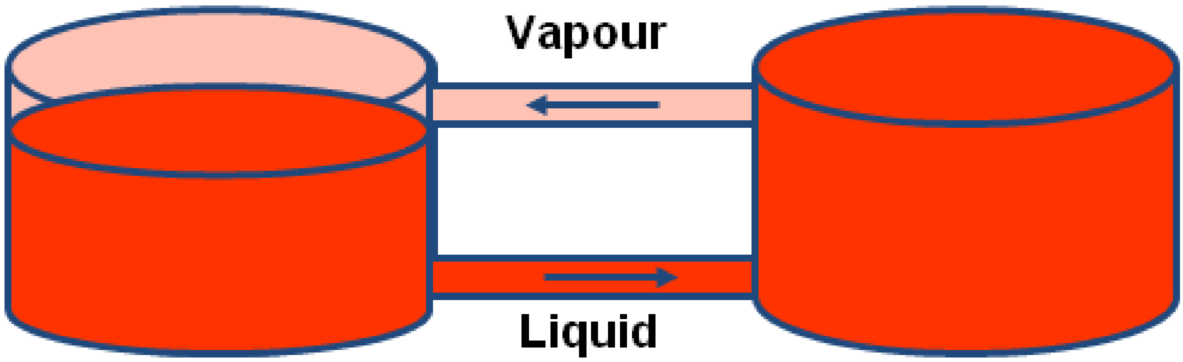
Appendix 14: Catylic oxidation schematic overview



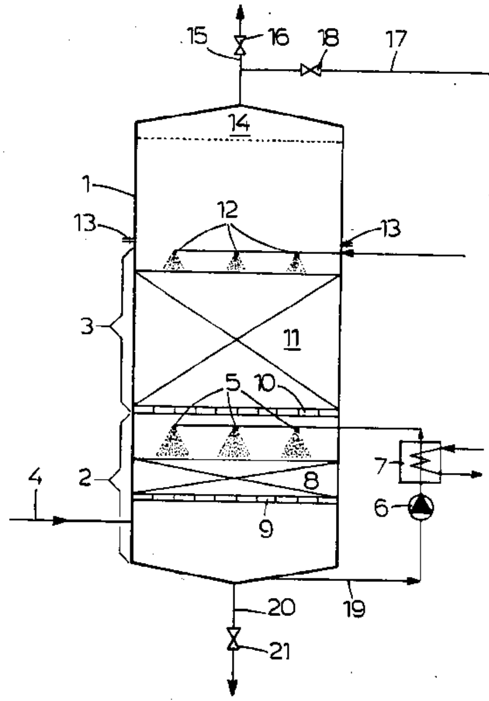
Appendix 15: Washing schematic overview



Appendix 16: Vapour balance system schematic overview



Appendix 17: Biological treatment system schematic overview



The container 1 which in this embodiment is cylindrical is composed of a pretreatment chamber 2 for the waste gases and a filter unit 3. In the pretreatment chamber is provided the supply conduit for the gases to be treated 4 and the support layer 9 which in this embodiment is a perforated metal plate. The pretreatment chamber may be arranged separately from the container. On the support layer 9 a gravel bed is provided for enhancing the contact between the upward gas-stream and the downwardly sprayed liquid. Up in the pretreatment chamber 2 spraying means 5 are provided. Down in the pretreatment chamber 2 the spray water may be tapped through the discharge conduit 20 and the valve 21 or it may be circulated through the circulation conduit 19 including the circulation pump 6 and the heat exchanger 7. In the heat exchanger 7 the spray water can be brought to the desired temperature, i.e. when a higher temperature is desired, the spray water can be heated in the heat exchanger or when a lower temperature is desired, the spray water can be cooled. Above the pretreatment chamber 2 is provided the filter unit 3 separated by the gas permeable support plate 10 on which rests the biologically active zone 11. The biologically active zone 11 can be composed of the carrier material alone but preferably of a mixture of carrier material and the previously discussed additional materials. Above the biologically active zone 11 are provided sprayers 12 which in case of emergency, for example, when the spraying means 5 in the pretreatment chamber 2 should fail, can secure the moistening of the biologically active zone. On the filter unit 3 is fastened the top section 14 through the fastening means 13, for example a screw means. The biologically filtered gas can now be discharged to the atmosphere through the discharge 15 and the valve 16 or it can be conducted through the conduit 17 and the valve 18 to a measuring and sampling apparatus. On the filter unit 3, if desired, a plurality of filter units can be arranged which then can be fastened together by a similar fastening means as 13, for example. For convenience, such fastening means can be a screw means. The use of more than one filter unit can be necessary in cases wherein the waste gases to be treated contain components requiring for their decomposition different conditions possibly including different micro-organisms or when the waste gases to be treated include one certain component in such a high concentration that the capacity of one filter unit is inadequate for sufficiently decomposing it. By a uniform construction of the filter units the apparatus of the invention, if desired, can be adapted to biologically leaning various waste gases of different compositions by simple fastening the said filter units on each other.

The principle of multiple filter units can also be applied by dividing a gas stream to be treated into two of more equal streams and by conducting the separate streams to separate filter units disposed above each other in one column. When the method is effected in such an apparatus, a considerable further reduction of the pressure drop of the gas stream through the filter can be reached. This decrease of the pressure drop for two units arranged inparallel theoretically amounts to a factor 4 in comparison with the case of two units in series: namely a factor 2 for the reduction of the gas loading per m.sup.2 of filterarea traversed and a factor 2 for the reduction of the filter height.

Appendix 18: Degassing techniques specifications review

Techniques	Direct degassing	Dedicated transport	Load on top	Scrubber	(catylic-) oxidation	(membrane) filtration	condensation	(Cryo-) condensation		Adsorption (activated carbon)		Vapour balance system	Ionisation	Biological treatment	Incineration	Micro gas wash	Washing
Specifications							Condensation STS Ventoclean	(Cryo-) condensation AQ linde	(Cryo-) condensation Mariflex/purgit	Regenerative	Sacrificial filter beds		Ion2Air			Vaprosol	
Applicibility	Only allowed at allocated places. Prohibited during certain weather conditions	Applicable at all time	Applicable when substances are compatible	Only if substance is disolvable in water & compatible with detergent	Only applicable for substances with a maximum VOC-concentration of 10g/Nm3	Applicable at all time, but always has to be in combination with a scrubber or/and a cooler/condenser	Applicable at all time			Applicable at all time, but always has to be in combination with a scrubber or/and a condenser or for certain substances a specific design is needed		Applicable at all time	Applicable at all time	Only applicable with low VOC-concentrations and requires a continious flow	Most incereration techniques are always applicable.	Applicable at all time	Applicable at all time, but not likely
Availability	Available	Available	Available	Available	Available	Available	Techniques in testing phase			Available		Available	Technique in testing phase	Available	Available	Technique in testing phase	Available
Capacity	Dependable on movement of ship	N.A.	N.A.	10.000 - 15.000 m3/h Depends on size	Depends on size of pipes	between 800 - 1500 m3/h depends on size of pipes	2000 up to 2500 m3/h (depending on condensation temperature)	500 m3/h	600 m3/h (expected to be increased up to 1100 m3/h)	On board: 1000 m3/h On-shore: 2000 m3/h		1000 m3/h Depends on piping, (detonation)-arrester and valves	5000 m3/h	50 - 150 m3/h in small batches	1000 m3/h Depends on piping, (detonation)-arrester, valves and vapour buffer	5000 m3/h	5000 m3/h
Product variety	Suitable for all substances	Suitable for all substances	only suitable when substances are compatible	Suitable for all substances which are disolvable in water	Only suitable for substances with a maximum VOC-concentration of 10g/Nm3	Not very suitable for very volatile products	Not very suitable for very volatile products	Less suitable to treat high benzene concentrations due to solidifying of substance	Less suitable to treat high benzene concentrations due to solidifying of substance	Boiling point of VOC substance must be above 30 degree Celcius		Suitable for all substances	Suitable for all substances	Not suitable for high VOC-concentrations	Suitable for all substances	Suitable for all substances	All substances which are compatible with water
Recovery	No recovery of substance	N.A.	N.A.	Recovery of substance possible	No recovery	With scrubber and cooler/condenser possible recovery of substance	Possible recovery of substance	Possible recovery of substance	Possible recovery of substance	Possible recovery of substance	No recovery of substance	N.A.	No recovery of substance	No recovery of substance	No recovery of substance	Possible recovery of substance	Possible recovery of substance
Suitable platfomrs	On board	N.A.	N.A.	Shore based	Shore based	On shore and floating	On shore and floating			On shore and floating	On board, floating and on shore	On shore / on board	On shore and floating	On shore	On shore or on board	On shore and floating	On shore and on board
Dimension	N.A.	N.A.	N.A.	Variable	N.A.	L x W x H = 8 x 6 x 6 weight: 16.000 kg	1 x 40ft Container sized	L x W x H = 3,2 x 2,4 x 4,3 weight: 3600 kg + nitrogen storage	L x W x H = 6,06 x 2,44 x 2,59 weight: 5.800 kg + nitrogen storage	L x W x H = 3 x 10 x 4,5 weight: 21.500 kg	L x W x H = 2,3 x 1,2 x 1,2	Variable	2x 20ft container sized	Approx. 2500 m2	From 40ft container sized	1 x 40ft Container sized	Variable
cost estimate - (C)APEX / (O)PEX	None	Cost of carrying dead freight	N.A.	Very dependable on size of installation	Very dependable on size of installation	C: 1.390.000 O: 20.000 per degassing cycle	C: 1.680.000 O: 864.712	C: 833.450	O: 1.373.409	C: 254.150	O: 809.971	C: 58.000 O: 95.000	Not yet known	C: 2.000.000 O; 1.000 per m3	C: 2.412.000 O: 250.000	Based on a total cost of ownership	C: 1.375.000 O: 278.500
Average duration	8 hours average	N.A.	N.A.	Very dependable on size of installation	Very dependable on size of installation	Depends on size of vessels, piping, stripping of vessel and concentration of VOC	Not yet tested	Not yet tested	Not yet tested	8- 10 hours	15 - 25 hours	Depends on size of vessels, piping, stripping of vessel and concentration of VOC	Not yet tested	> 8 hours	4- 10 hours depends on size of barge	6 - 7 hours	4- 10 hours depends on size of barge
efficiency	Up to 99%	100%	100%	VOC removal up to 90 - 99 %	VOC removal up to 60 %	VOC removal up to 90 - 99 %	Up to 99% Much lower for very volatile products	Up to 99% Benzene and high humidity is a concern (will cause ice/solidification)		Up to 99% Adsorptive ability acetone & methanol are satisfactory, most other good.		100%	Up to 99%	up to 80%	Up to 99%	VOC removal up to 80 - 90 %	Up to 99%
Safety assesment	If degassed under the LEL criteria and all ADN specifications are met, no directt safety hazzard	N.A.	N.A.	From the viewpoint of fire and explosion hazards, the absorption technology is relatively safe. An explosion-proof installation is advised		In practice, this technology is indeed applied for the separation of flammable components in concentration ranges, which are in the explosion regimes (e.g. gasoline vapour). It can be assumed that the appropriate safety pre-cautions are applied on board of the barges. Nevertheless, the installation of such system in the circumstances considered always has a certain risk element	The operation with condensation installations is not associated with particular risks. The use of compressors and refrigeration units can be a source for ignition if not properly designed. The gas vapour systems therefore need to be physically separated (sealed) from the compressor units	High intrinsic safety due to lack of ignition sources, No hazardous items in vapour path requiring services	High intrinsic safety due to lack of ignition sources	Ignition of the coal is possible at high loading rates and insufficient cooling, Local overheating due to dead spaces is an often-observed phenomenon in adsorption operations. It cannot be excluded in this envisaged treatment plant: the beds are installed on a moving ship and it is possible that settling of the bed occurs which leads to "dead spot		As the saturated vapour may contain droplets of organic liquids the generation of static electricity is a risk. In order to avoid this risk the vapour velocity should be restricted to maximum 17 m/s	Although the ionisation technique is not yet operational tested, safety precautions are made. The Ionisation unit is a seperated into two parts, the proccess chamber which contains all the techniques and the so called gas chamber which holds up the gas in after it is processed.	Regarding fire and explosion hazard bio-filtration is relatively safe technology. For the necessary purging equipment an explosion safe version is recommended	When applying the post-combustion (also closed flare) technology it is essential to exclude any possibility of flame backfiring in the vapour collection piping. The most important means, which have been proven in the industry, are: sufficiently high gas velocities (to exceed the flame velocities) and in addition, installation if flame-arrestors in the gas feed pipes.	Ignition of the coal is possible in the first active coal filter at high loading rates and insufficient cooling	From the viewpoint of fire and explosion hazards, the absorption technology is relatively safe. An explosion-proof installation is advised

Appendix 19: Degassing techniques Balanced scorecard

Techniques	Factors	Direct degassing	Dedicated transport	Load on top	Scrubber	(catylic-) oxidation	(membrane) filtration	condensation	(Cryo-) condensation		Adsorption (activated carbon)		Vapour balance system	Ionisation	Biological treatment	Incineration	Micro gas wash	Washing
Specifications								Condensation STS Ventoclean	(Cryo-) condensation AQ linde	(Cryo-) condensation Mariflex/purgit	Regenerative (PSA)	Sacrificial filter beds		Ion2Air			Vaprosol	
Availability	2,0	4	5	5	3	2	5	1	2	1	4	2	3	1	1	5	2	4
Capacity	1,0	4	3	3	5	2	4	4	2	3	4	3	3	4	1	4	4	4
Product variety	1,0	5	5	2	3	2	4	3	4	4	3	4	4	5	2	4	4	3
Recovery	1,0	1	5	5	5	1	3	5	5	5	4	4	1	1	1	2	5	4
sustainability	2,0	1	2	5	3	2	4	5	5	5	5	3	4	3	5	2	5	4
Suitable platforms	1,0	5	5	3	3	1	4	3	3	3	3	5	5	3	1	5	4	5
cost estimate (C)APEX	1,0	5	5	5	2	3	2	2	3	3	4	3	4	2	1	1	3	2
cost estimate (O)PEX	1,5	5	2	5	2	4	2	3	2	2	1	1	5	4	2	4	2	2
Average duration	1,0	5	3	3	3	4	2	1	1	1	2	2	3	3	1	4	3	3
efficiency	2,0	3	3	5	4	1	4	3	3	3	5	4	5	4	4	5	4	4
Safety assesment	1,0	1	5	4	4	2	3	3	5	5	3	3	1	2	4	3	2	4
Total	14,5	49,5	54	62,5	48	31	51	43,5	46	45	52,5	43,5	52,5	42	34	53	50	52

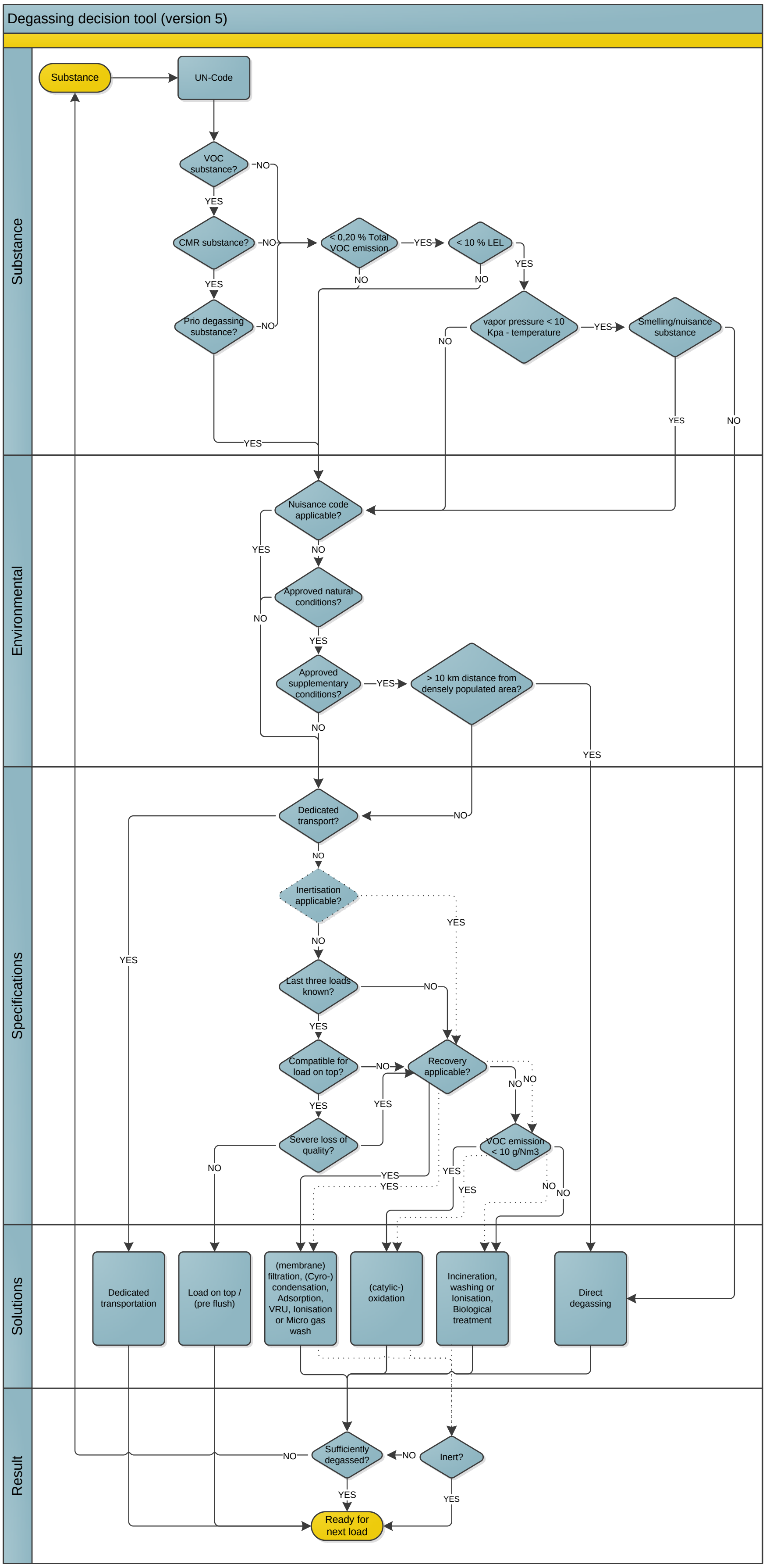
Appendix 20: Degassing techniques SWOT-analysis

Technique:	Strengths	Weaknesses	Oppertuinities	Threats
Direct degassing	No additional equipment needed, Can be conducted while sailing	Non environmental friendly, prohibited in certain area's and in certain conditions, no recovery of substance, vessel must be in movement to reach relative quick degassing,		on long-term eventually prohibited
Dedicated transport	No additional equipment needed, exept dead freight costs no additional costs, relatively cheap, no additional degassing transit times, no degassing required before loading, No emissions (only before a planned / unplanned wharf stopover)	Empty barge movement, Reduction of the overall capacity	With better planning of barge deployment and dedicated networks, higher utilization and efficiency can be achieved and less barges need to be degassed	Increased volume of traffic could be a the consequence of more dedicated sailing, which will form a threat for the environment and the jettie occupation
Load on top	Product change without need of previous ventilation possible and therfore a reduction of number of ventilations (and emissions), Higher flexibility compared to dedicated transports	Only compatible of certain substances, may lead to loss of quality of substance, needs to be in combination with a VRS to create a closed loop, Contamination of the new product by residuals of the “old” product possible	With better planning of orders with compatible substances in sequence, higher utilization and efficiency can be achieved and less barges need to be degassed	Higher demands of quality will lead to less possibilities for the load on top solution
Scubber	Can be conducted on large scale, relative quick solution	Only applicable if substance is disolvable in water and compatible with detergent, residual water mixed with substance,	A potential re-use of the substances can be realised, which can create a sustainable and profitable solution	this technique is only suitable with substances disolvable in water and compatible with detergent, this results in a smaller range of products which are suitable to process vapour and forms a disadvantage in comparison to other techniuques
(catylic-) oxidation		Only applicable for substances with a maximum VOC-concentration of 10g/Nm3, low efficiency		Because this technique has a small(er) range of products which are suitable to process vapour it has a disadvantage in comparison to other techniuques
(membrane) filtration	Proven and reliable technique but does not meet European air emission limits, so must be used in closed loop modus with recycle of vent gases back into the ship or combined with a polishing technique	Always has to be in combination with a scrubber or/and a cooler/condenser, Not very suitable for very volatile products, All chemicals need to be checked for compatibility with the membrane	A potential re-use of the substances can be realised, which can create a sustainable and profitable solution	Compared with the other techniques there still is a relative operational cost, due to the activated carbon.
(Cryo-) condensation AQ Linde	Recovered product can be obtained pure. Used nitrogen can be emitted into air, Very high VOC recovery rate	Less suitable to treat high benzene concentrations due to solidifying of substance, High cost of operation, Not yet available on market, the condensors have defrost cycles which takes extra time for degassing, an extra heat exchanger is necessary for condensed aerosols in the vapour flow	A potential re-use of the substances can be realised, which can create a sustainable and profitable solution	This technique is less suitable to treat high benzene concentrations, this results in a short-term disadvantage becuase the prohibitation is directed on benzene and benzene containing substances
(Cryo-) condensation Mariflex/purgit	Recovered product can be obtained pure. Used nitrogen can be emitted into air, With two stage techniques very high removal rates can be achieved.	Less suitable to treat high benzene concentrations due to solidifying of substance, Not yet available on market, Energy consumption will be higher due to two stage design. the condensors have defrost cycles which takes extra time for degassing, an extra heat exchanger is necessary for condensed aerosols in the vapour flow	A potential re-use of the substances can be realised, which can create a sustainable and profitable solution	This technique is less suitable to treat high benzene concentrations, this results in a short-term disadvantage becuase the prohibitation is directed on benzene and benzene containing substances
Condensation STS Ventoclean	Recovered product can be obtained pure. Used nitrogen can be emitted into air, More suitable to treat high benzene concentrations due to controllable condensation temperature	Not yet available on market, Not very suitable for very volatile products, For very volatile products (such as MTBE), it will be difficult to reach low emission concentrations, Significant maintenance is required	This technique has an oppertuinity in the raise of the demand of inert ships, becuase this technique makes vessels inert at the same time of vapour removal it benefits from this trend. A potential re-use of the substances can be realised, which can create a sustainable and profitable solution	This technique is not very suitable to treat very volatile products, this results in a smaller scope of products which can be degassed, this results in a smaller range of products which are suitable to process vapour and forms a disadvantage in comparison to other techniuques
Adsorption	Recovered product will be dissolved in the scrub medium, this can be avoided by using a condenser instead of a scrubber but energy consumption will be higher, Small units can be installed on board of barges	Always has to be in combination with a scrubber or/and a condenser or for certain substances a specific design is needed, Boiling point of VOC substance must be above 30 degree Celcius, Saturated carbon must be processed, Ignition of the coal is possible at high loading rates and insufficient cooling, the condensation of an installation depends on many factors	A potential re-use of the substances can be realised, which can create a sustainable and profitable solution	
Vapour balance system	No polution, high availability, no loss of substance	Not always meets standards of VBS in form of sustainability, If one vessel is inert it will not acept the vapour form a vessel which is not inert, various substances which are balanced into the same tank may form an explodable mixture	Due to the high availibility and proven working of the technique it is possible to be used more often for the removal of vapours	If one vessel is inert it will not acept the vapour form a vessel which is not inert, various substances which are balanced into the same tank may form an explodable mixture, this results in refusal for the degassing of of the vessel from the vapour processing facility
Ionisation	Relative quick handling time, no waste	No recovery of substance, not yet tested, does not need extra fuel like incineration process	Still in development phase, other techniques might the technical need before this technique is available	if operational a more sustainable variation of incineration (no additional fuel needed)
Biological treatment	Environmental friendly	VOC concentrations are too high, Operations flow must be continuous, low efficiency, the installation will require a lot of space		Operations flow must be continuous for this technique, this is not a realistic demand
Incineration	Relative quick handling time, suitible for all platfoms, heat recovery possible, high efficiency	Not environmental friendly, for thermal combustion a continuous gas stream is necessary	This technique has a realtive short average duration, this forms an advantage in comparison to other available techniques	This technique still has a impact on the environment and is therfore less sustainable
Micro gas wash Vaprosol	Recovery of product, Low energy use, Low energy and utility consumption Relatively high capacity related to the footprint of the installation	Residual product is mixed with water and soap, Not yet available on market, Saturated carbon must be processed, hotspots might occure in the first active coal bed	A potential re-use of the substances can be realised, which can create a sustainable and profitable solution. High-tech software of is an oppertuinity for legislation in the future	May encounter difficulties with inert ships
Washing	Proven technology, High availibility, can be combined well with other techniques	The substance must be disolvable in water, oils are therefore less suitable, efficiency is relatively low	A potential re-use of the substances can be realised, which can create a sustainable and profitable solution	The substance must be disolvable in water, oils are therefore less suitable, this results in a smaller range of products which are suitable to process vapour and forms a disadvantage in comparison to other techniuques

Appendix 21: Stakeholders/actors function

Stakeholder	Function
Barge(fleet)owners	This group exists of all the companies which are responsible for the transport of liuid chemicals, oils and minerals. Which exists of, but not limited to: Interstream barging, Unitas/GEFO, Jaegers GmbH,Oil majors owned fleet and individual chartered bargeowners
BLN	(Binnenvaart Logistiek Nederland) This overaching branche organisation is committed for both specific interests of entrepreneurs as for collective needs of the barge sector representive for: shipping companies/entrepreneurs, barge owners, charterers and operators (representing over 50% of this sector)
CBRB	(Centraal Bureau Rijn- en Binnenvaart), CBRB is the largest employer organisation and business organisation in inland barge transport in The Netherlands. The members of the CBRB are represented in all major and sub-sectors of the inland barge transport sector, both at the level of the carrier and that of transport organiser. CBRB also has an extensive network of associate members who are involved in the inland barge transport sector
Cefic	Cefic is the forum and the voice of the chemical industry in Europe, Cefic is a committed partner to EU policymakers, facilitating dialogue with industry and sharing their broad-based expertise. Cefic represent 29,000 large, medium and small chemical companies in Europe, which directly provide 1.2 million jobs and account for 20% of world chemical production. Cefic interacts on behalf of their members with international and EU institutions, non-governmental organisations, the international media, and other stakeholders
DCMR	(Dienst Centraal Milieu Rijnmond), The DCMR is the joint environmental protection agency of the province of South Holland and 16 municipalities, a heavily industrialised and densely populated region. The DCMR monitors the environmental quality of this area in close cooperation with other government agencies, such as the police, the fire department, the labour inspectorate, and the public health service
Deltalinqs	Deltalinqs represents the common interests of all the logistical and industrial companies in the Rotterdam port and industrial area. The organisation is considered to be the focal point and spokesman for more than 700 registered companies and associations
EBU	(European Barge Union), The aim of the association is to represent the interests of inland navigation on a pan European level and to deal with all questions, arising out of the future development of the inland navigation industry and inland waterway transport
Europia	EUROPIA contributes in a constructive and pro-active way to the development of policies to safeguard the secure and sustainable manufacturing, supply and use of petroleum products, by providing competent input and expert advice to the EU Institutions, Member State Governments and the wider community
Gas processing parties	This group exists of all the companies which deliver the techniques for the controlled degassing of barges and/or execute the controlled degassing. Which exists of, but not limited to: Vaitec/Vorporsol, Ipco Power, LTT, Mariflex, ATM Moerdijk, Rubis, AQ Linde, Desotec and Ventoclean STS
GTRS Comittee	Conscious of the need to develop a framework enabling to handle gaseous residues of liquid cargo transported by inland tanker shipping, a steering committee has been set up by a number of stakeholder organisations including seaports, chemical and petro-chemical industry, shipping industry and storage companies. With regard to the set objectives, the SC considered it its prime mission to promote initiatives in view of a framework for controlled degassing in inland shipping. Whereas the SC has set the goal to develop "without delay international guidelines for the handling of gaseous residues of liquid cargo remaining in the tanks of inland tanker barges, it has concentrated its deliberations on the basic principles of such a framework and has taken initiatives enabling the competent authorities to undertake the measures concerned.The GRTS Steering Committee has set The present document reflects the state of affairs of the GRTS Steering Committee
ILT	(Inspectie Leefomgeving en Transport) The Environment and Transport Inspectorate of the Ministry of Infrastructure and the Environment monitors and encourages compliance with laws and regulations for safe and sustainable environment and transportation
Oil majors	The oil majors are vertically integrated oil, chemicals and gas companies involved in all stages of the industry. Fot instance: Shell, Exxon mobil, BP, Lyondell and Total
Port of Amsterdam	The Port of Amsterdam Optimises service and business climate for companies in the port region. To this end the port focuses on existing clients attracting new cargo flows, new businesses and also on marketing and promotional activities. Constructs and maintains infrastructure, modernise the port and manage Amsterdam's port area Westpoort. Ensures prompt, safe and environmentally friendly shipping traffic from 40 kilometres outside the pears near IJmuiden to the Orange Locks
Port of Antwerp	The Port of Antwerp has been an indispensable link in world trade since the Middle Ages. Today, 150,000 people contribute to this success story and there is a close co-operation between private enterprises, the authorities and the Port Authority. All these people and parties contribute to a prosperous and sustainable future for the Port of Antwerp and its surroundings
Rijkswaterstaat	Rijkswaterstaat part of the Dutch Ministry of Infrastructure and the Environment, the former Ministry of Transport, Public Works and Water Management. Its role is the practical execution of the public works and water management, including the construction and maintenance of waterways and roads, and -importantly- flood protection and prevention
Royal HaskoningDHV	Royal HaskoningDHV is a independent, international engineering consultancy service provider. It specialises in asset management, aviation, buildings, energy, industry, infrastructure, maritime, mining, strategy, transport, urban and rural planning, water management and water technology
Traders	Independent physical traders in the global fuel oil market trade oil and chemicals from suppliers of feedstocks to refiners of the substances. Examples of traders are: Vitol, Trafigura and smaller independent traders
VNCI	The Association of the Dutch Chemical Industry (VNCI) promotes the collective interests of the chemical industry in the Netherlands by means of consultations, information meetings and recommendations. The VNCI acts on behalf of the entire sector as a central contact point and undertakes activities that have a positive impact on the image of the chemical industry
VNPI	The association of the Dutch petroleum Industry (VNPI) promotes the collective interests of the Petroleum industry in the Netherlands by means of consultations, information meetings and recommendations. The VNPI acts on behalf of the entire sector as a central contact point and undertakes activities that have a positive impact on the image of the petroleum industry
VOTOB	(Vereniging van onafhankelijke tankoplagbedrijven), VOTOB has 16 members which account for almost all independent tank storage capacity in the Netherlands. Independent means that the storage companies do not own the products they store

Appendix 22: Degassing decision tool



Appendix 23: Risk indication panel

Objective	Risk area	Indicators	Description	Impact
Operational feasibility	Shipper	Inland barge transport may lose its competitive lead compared to other transport modes	The entire supply chain of inland tank vessel transport with all active stakeholders must not be obstructed by the consequenses of a phased direct degassing prohibtion. This may lead to a enfeeblement of the current competitive lead compared to other transport modes.	1
		All-in tariffs with charterers, which create a lower threshold for direct degassing	When a barge (owner) is chartered for a certain transport and charges an all-in tariff per hour for the transport which is executed. The time estimated for degassing of the barge is taking into account and added up with the total required transport time, which will form together the total charged time. This will create a lower threshold for direct degassing, because in this manner direct degassing has no direct effect on the cost effectiveness and is not considered as 'lost' time. In some cases barges will even take a detour for the purpose of degassing.	3
	Filler	High jetty occupation which forms congestion	Fillers (tank storage companies and terminals) have a high jetty occupation. This occupation will only increase by the placement of a shore based gas processing installation. Fillers reserve these available jetty space for more profitable business.	4
		VRU-systems are in use for own operations	The most common reason for direct degassing from a charterer's perspective is the lack of a vapour recovery systems on the land side which can be used. This is related to the high jetty occupation of terminals. Mostly terminals use their VRU-systems for their own processes (dedicated use).	4
	Trader	The load which is transported by inland tank vessels can traded between various owners during transport	The load of barges continuously switches of owner within the supply chain. The reason for this is because the product can be traded several times when moving through the supply chain. Due to this complicated ownership of freight within the supply chain, it is unclear which actor is eventually responsible for the residual after unloading the product. This makes the barge owner responsible for the degassing of barges and makes them responsible for the corresponding costs and loss of time.	5
	Expeditor	The uncertainty of the knowledge of a next possible load which results from poor collaboration within the supply chain	Raising quality requirements and the uncertainty of the knowledge of a next possible load form a threat to logitical solutions for the degassing of barges such as (load on top and dedicated transport) this can be mended by supply chain collaboration.	4
	Charterer	A lack of insight within the supply chain	The directing role of the supply chain is in the hands of the shippers and Exepeditors. The barge/fleet owners are in a reactive role in this situation this is creates a lack of insight.	3
		Increase of flexibility of barges which results in unnecessary degassing	Because of quality requirements and the uncertainty of the knowledge of a next possible load, the market for charterers becomes more competitive and barge owners tend to be as flexible as possible. This has as consequence that the barge owner will degas as soon as possible to not be obstructed by these demands. In cases there might be a compatible load as next load and the degassing of the barge is unnecessary.	5
	Receiver	The re-use of molucules within the supply chain must not lead to an increase of costs	The most sustainable way for degassing inland tank vessles is to recover the gaseous residual of substances and re use it as liquid product within the supply chain. If this is not feasibile/proiftable other sustainable ways for degassing might be more realistic.	2
		Possible additional cost for dagassing	The concept of sustainable degassing is to enhance the environment within the banche of inland tank transport. This may not lead to a considerable raise of costs which are made during the movement through the supply chain.	2
Technical feasibility	Shipper	An increase in dedicated transport will form an increase of the total traffic volume of inland barges	When the amount of dedicated sailing ships increases there are more ship movements, this can result in higher jetty occupation and/or utalization of vapout balancing systems. Additional, empty sailing barges might also have a negative effect on the sustainability.	2
		The demand of inert vessels can create more difficulties for degassing	There is a higher demand for inert vessels, these inert vessel will encounter issues with degassing when vapour balancing or at a vapour return system. Inert vessels will not take gaseous residues or liquid VOC's of a ship which is not inert. This lowers the possibilities for degassing of an inert ship.	4
	Filler	Shore based degassing installations will increase the jetty occupation	Higher jetty occupation and/or utalization of vapour balancing systems/vapour return systems might be in order if these handlings are shore based.	4
		An increase of the total traffic volume of inland barges may lead to jetty congestions	When the amount of dedicated sailing ships increases there are more ship movements. Therefore higher jetty occupation and/or utalization of vapour balancing systems might be in order if these handlings are shore based.	2
	Trader	No direct risks	N.A.	0
	Expeditor	At a certain point logistical solutions will be no longer be possible and the marktet is forced to be dependable of technical developments	Logistical solutions, which optimize the transport of the entire fleet of deployed inland tank barges within the supply chain are primarily effective on short term. Eventually proven or promising techniques for controlled degassing must be used to fill the demand for the degassing of inland tank vessels.	3
	Charterer	Barge(fleet)owners tend to be more cost-effective focussed than sustainability focussed	Because of the low demand of inland tank transport, the barges do not have a direct consecutively order. Due to this unused time it is more likely to degas at the highest cost-effectiveness, instead of taking sustainability or duration into account, which in most cases leads to direct degassing. When the demand of inland tank transport increases the barge(fleet)owners will experience more importance in for instance the duration of degassing, which will eventually help developing the gas-processing techniques for mutual benefit.	4
		The lack of gas treatment plants	When the phased prohibition of dirrect degassing is active, there must be sufficient gas processing plants/units available to handle the degassing demand which previously degassed direct into the air.	5
	Receiver	Techniques which make the re-use of molucules possible are testing phase	These techniques require are tests from which they can learn and adjust their technique and eventually reach the level of an operational usable technique to degas inland barges.	5
		The market is dependable of the development of techniques and vice versa, which results on slow developments of techniques	The techniques which are in testing phase are all very promising in theory. What these techniques require are tests from which they can learn and adjust their technique and eventually reach the level of an operational usable technique to degas inland barges. However the entire market with all its actors of inland barge transport are waiting for the most suitable technique to be fit for their use and the technique suppliers are waiting of reaction and interaction of the market. Due to this construction the development of techniques improves slowly.	4
Law & legislation feasibility	Shipper	The prohibition must be performed gradually, or else the market might have negative consequenses for the entire market	The prohibition of the degassing of barges must be executed within a period of seven years (2014 – 2020). It is key that the phased prohibition is performed as gradually as possible divided over these seven years.	3
	Filler	There are no clear legislation demands for a floating gas processing installation	There is lack of clear laws and legislations to which a floating degassing installation (placed on a pontoon) must suffice. This lack creates not only a unclear perspective about the level of degassing, but also an unclear perspective of the technical, safety and environmental demands to which a floating degassing installation must suffice. This makes the task of the provider of the relevant degassing techniques to create a suitable platform for a applicable degassing technique more complicated.	4
	Trader	Due to the switches of ownership of transported loads no party feels responsible for the residual gasses	A vital element within the re-use of chemicals principle is the degassing as a physical operation, which needs to be seen as a disconnected part from the unloading procedure. However, degassing is an aspect of the total physical distribution as such. The responsibility for the correct execution of the degassing and the delivery of the degassed cargo tanks therefor needs to be specified in which parties are responsible for which operation within the supply chain. The shared responsibility of parties in the supply chain needs to be worked out in a detailed level, taking into account the need of collaboration, transparency and market uniformity in the supply chain, before legal obligations and regulated laws and legislation can be introduced.	5
	Expeditor	The residual gasses in an inland tank vessel are categorised as waste	To realise an effective re-use of chemicals the current laws and legislation must be in line with the operational re-use of chemicals. An essential aspect concerns the qualification of the cargo vapours, respectively the liquefied gaseous residues in terms of waste treatment. Liquefied vapours and gasses from previous cargos should therefore not be defined as waste. In this order the respective volumes could be reintegrated in the supply chain. The procedures and reglementary framework should be in line with the re-use of chemicals principle.	4
	Charterer	There is no clear description of 'gas free' due to the gap of interpretation of legislation between safety and environment	Due to the different levels of laws and legislation and different perspectives/purposes of the interpretation of degassing it is unclear about when a vessel can be declared 'Degassed'. The standard which is used are the standards described in the ADN, which is the level of <10% of the lowest explosion limit (LEL), this legislation is from a safety point of view. This differs from an environmental point of view and must be seen in separate perspective. An environmental point of view are stated in the NER (The Dutch emissions guidelines) and the WABO (The General Provisions of Environmental Law).	5
		When the prohibitation for direct degassing is not uniformly implemented, so called: 'degassing tourism' might take place	Although there is no regulation of the active direct degassing prohibitions in Germany, the barge(fleet)owners postpone the direct degassing within the German waterways and start direct degassing when passing the border and reaching The Netherlands or other countries which have a less strict direct degassing prohibition. This creates a flow of liquid free vessels which need to be degassed, this can be described as 'direct degassing tourism' which takes place.	5
	Receiver	The supply chain concerning the degassing of inland tank vessels is very complecated, this makes it difficult to get support from all actors	The playing field concerning the degassing of inland barges is very complicated. There are many parties with in some cases mixed interests. This can have negative consequences for the collaboration and transparency between parties.	4

Appendix 24: Trade-off controlled degassing versus dedicated transport

Characteristics prevalent ship	
Width	13,5
Length	110
immersion (loaded)	4
Loading capacity (tons)	4001 - 4300
Speed (loaded)	15
Speed (unloaded)	20

	Ship type	
ADN type	Double hulled	Sigle hulled
Type C	670	2
Type G	79	0
Type N	215	1231
Total	**964**	**1233**

Transport costs	Average transport costs (tariff per hour)				Average transport costs (tariff per kilometer)	
	Loaded sailing cost	Empty sailing cost	Loading/unloading cost	Waiting cost	Loaded sailing cost	Empty sailing cost
RVS ship	€ 807,28	€ 685,99	€ 524,94	€ 498,76	€ 48,00	€ 38,40
Coated ship	€ 622,76	€ 501,47	€ 340,42	€ 314,23	€ 37,46	€ 27,85
Single hulled ship	€ 512,15	€ 390,87	€ 229,81	€ 203,63	€ 31,14	€ 21,53
Average tariff	**€ 647,40**	**€ 526,11**	**€ 365,06**	**€ 338,87**	**€ 38,87**	**€ 29,26**

Measured distances (from Rotterdam)		
Destination	Distance (km)	Travelling time
Amsterdam	115	0d 10:10
Antwerpen	116	0d 10:40
Düsseldorf	252	1d 06:30
Koblenz	412	2d 03:40
Basel	840	4d 10:10

Cost estimate dedicated transport							
Destination	Loaded sailing cost	Loaded sailing time	Empty sailing cost	Empty sailing time	Waiting cost (4h)	Loading/unloading cost (8h x 2)	Total
Amsterdam	€ 4.469,67	7,67	€ 3.364,90	5,75	€ 1.355,49	€ 5.840,91	**€ 15.030,97**
Antwerpen	€ 4.508,53	7,73	€ 3.394,16	5,80	€ 1.355,49	€ 5.840,91	**€ 15.099,09**
Düsseldorf	€ 9.794,40	16,80	€ 7.373,52	12,60	€ 1.355,49	€ 5.840,91	**€ 24.364,32**
Koblenz	€ 16.013,07	27,47	€ 12.055,12	20,60	€ 1.355,49	€ 5.840,91	**€ 35.264,59**
Basel	€ 32.648,00	56,00	€ 24.578,40	42,00	€ 1.355,49	€ 5.840,91	**€ 64.422,80**

Cost estimate controlled degassing at installation							
Destination	Loaded sailing cost	Cost estimate for degassing	Waiting cost (4h)	Empty sailing time (4h)	Waiting cost (4h + 8h for degassing)	Loading/unloading cost (8h x 2)	Total
Amsterdam	€ 4.469,67	€ 3.000	€ 1.355,49	€ 2.104,44	€ 4.066,48	€ 5.840,91	**€ 20.836,99**
Antwerpen	€ 4.508,53	€ 3.000	€ 1.355,49	€ 2.104,44	€ 4.066,48	€ 5.840,91	**€ 20.875,85**
Düsseldorf	€ 9.794,40	€ 3.000	€ 1.355,49	€ 2.104,44	€ 4.066,48	€ 5.840,91	**€ 26.161,72**
Koblenz	€ 16.013,07	€ 3.000	€ 1.355,49	€ 2.104,44	€ 4.066,48	€ 5.840,91	**€ 32.380,39**
Basel	€ 32.648,00	€ 3.000	€ 1.355,49	€ 2.104,44	€ 4.066,48	€ 5.840,91	**€ 49.015,32**

Formula			
controlled degassing at installation		dedicated transport	
x	**b**	**x**	**b**
38,87	12300,89	68,13	7196,45
	5104,44	29,26	
	174,45	x	

Appendix 25: Increase compatibility and dedicated transport

New % degassed	Old % degassed	Degassed ships	Difference
29%	39%	58	-10%
0%	0%	0	0%
6%	46%	56	-40%
80%	90%	101	-10%
0%	5%	0	-5%
58%	68%	382	-10%
90%	100%	9	-10%
57%	67%	73	-10%
90%	100%	95	-10%
6%	16%	6	-10%
90%	100%	7	-10%
0%	0%	0	0%
90%	100%	10	-10%
90%	100%	6	-10%
90%	100%	6	-10%
0%	10%	0	-10%
90%	100%	25	-10%
90%	100%	1	-10%
10%	35%	8	-25%
0%	0%	0	0%
90%	100%	5	-10%
8%	28%	374	-20%
0%	0%	0	0%
64%	74%	64	-10%
75%	85%	27	-10%
48%	58%	30	-10%
60%	70%	289	-10%
0%	0%	0	0%
0%	0%	0	0%
0%	0%	0	0%
69%	79%	102	-10%
70%	80%	286	-10%
0%	0%	0	0%
12%	22%	110	-10%
0%	0%	0	0%
87%	97%	521	-10%
90%	100%	1	-10%
40%	50%	117	-10%
90%	100%	61	-10%
90%	100%	22	-10%
65%	85%	127	-20%
90%	100%	9	-10%