H2020 Work Programme

D3.4 - BUSINESS AND RISK MODELS FOR INDUSTRIAL WH/C RECOVERY AND EXPLOITATION TOWARDS REPLICATION

Lead Contractor: IVL Swedish Environmental Research Institute

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Executive summary

The objective of this deliverable is to identify and evaluate business risk of industrial waste heat and cooling (WH/C) recovery. The point of departure is ongoing sites in Sweden due to their long-term experience in the area. The waste heat recovery in these sites has been ongoing for several years and there is ample information on risks to account for. To further understand the risk exposure to waste heat recovery investments pre-establishment, a mapping is made of the risk exposure of the demo sites in SO WHAT. From previous work it is known that the main risk discussed in the waste heat recovery context is the risk of industrial closure terminating the waste heat recovery. Therefore, attention is given to understand this risk as well as to map other risks of relevance in each site.

In addition, concerning renewable energy sources (RES) integration with WH/C recovery, there are possible operational risks associated to the fluctuating availability of RES production. Therefore, a special section has been dedicated to learning more about the risk impact of the RES volatility from the SO WHAT solutions.

It is identified that the risk of industrial closure, which was perceived as large in earlier studies with Swedish experience, has been evaluated as a risk with severe consequence but very low likelihood.

Other risks have been identified to have the highest scores (likelihood times consequence) in the risk heat maps derived:

- The lack of regulations or uncertainty in regulatory framework on waste heat recovery.
- The lack of technical know-how is getting high risk scores in the countries which historically lack district heating and cooling.
- For many demo sites the process to agree on pricing is considered as high risk: this is often a result from the two parties not knowing how the processes of the other party work.
- The dependence on one main heat source is also getting high risk scores; simply because a strong dependency is created where the stakeholders are reliant on a resource outside of its own control.
- It was identified that the importance of some risks is reduced over time. The risk of industrial closure is for example perceived to be lower once the relationship is established and up and running. In addition, a large volume heat recovery is seen as a riskier investment before it is undertaken whereas after it has been undertaken the large volumes instead have a stabilizing effect. Post investment other risks like perceived differences of the value of the waste heat (price) become more pronounced.

To summarise, the main finding was that that the different risks vary between European countries, industrial sectors and with choice of technology. However, the major part of the risks can be mitigated with well-designed contracts and well-thought-through partner arrangements: facilitating for the parties involved to learn about each other's processes.

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List of abbreviations

CHP	combined heat and power
DH	district heating
DHC	district heating and cooling
DHN	district heating network
ESCO	energy service company
HP	heat pump
PV	photovoltaics
RES	renewable energy sources
WH/C	waste heat and cold
WtE	waste to energy

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1 Introduction

The main objective of the Horizon 2020 project SO WHAT is to develop and demonstrate an integrated software which will support industries and energy utilities in selecting, simulating and comparing alternative industrial excess heat (IEH) and cold exploitation technologies that could cost-effectively balance the local forecasted heating and cooling demand, and also via renewable energy sources (RES) integration. An increased use of waste heat and cold has potential to decrease the European demand for primary energy and reduce the emissions of carbon dioxide.

The objective of work package 3 "SO WHAT tool outcomes: business model analysis" is to generate important information for attracting investments and for realizing industrial excess heat and cold recovery investments.

An important aspect for attracting investments is the concept of business risk. In this report, focus is on identifying and evaluating business risk of industrial waste heat and cooling (WH/C) recovery. The point of departure is ongoing sites (in Sweden). A unique study was made for all Swedish waste heat recovery collaborations between 1974 - 2014 to identify risk factors for waste heat recovery investments [1] and Sweden is also a progressor in waste heat and cold recovery.

The Swedish sites analysed consists of VEAB and GOTE and are together with IVL (as coordinator) also called the Lighthouse cluster in the SO WHAT-project. The waste heat recovery in these sites has been ongoing for several years and there is ample information on risks to account for. To further understand the risk exposure to waste heat recovery investments pre-establishment, a mapping is made of the risk exposure of the demo sites in SO WHAT. From previous work it is known that the risk mainly discussed in the waste heat recovery context is the risk of industrial closure terminating the waste heat recovery. Therefore, attention is given to understand this risk as well as to map other risks of relevance in each site.

In addition, concerning renewable energy sources (RES) integration with WH/C recovery, there are possible operational risks associated to the fluctuating availability of RES production. Therefore, a special section has been dedicated to learning about the risk impact of the RES volatility from the SO WHAT solutions.

We find that the different risks vary between European countries, industrial sectors and with choice of technology. However, the major part of the risks can be mitigated with well-designed contracts and well-thought-through partner arrangements: facilitating for the parties involved to learn about each other's processes.

First in the report, the theory of investment risk related to WH/C recovery is presented (Chapter 2), followed by a description of the methodology (Chapter 3) that has been used. Then, new knowledge about aspects related to closed waste heat cooperations in Sweden is presented (Chapter 4). The results of risk estimations for the SO WHAT demo sites are described (Chapter 5 and 6), followed by an analysis using risk heat mapping (Chapter 7). Finally, a concluding discussion is presented (chapter 8) followed by recommendations to the development of the SO WHAT tool (Chapter 9).

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2 Theory on investment risk

There is no such thing as a risk-free investment

In standard economic theory, it is assumed that actors are rational and therefore engage in maximizing the return whilst minimizing risk. However, it has been shown that few acts economically rational and individuals' understanding (cognition) of the world leads to different understandings of reality [2]. The cognition also impacts the assessment of investment value and risk and is reflected in the risk appetite of an investor. The rate of return required to make an investment will depend on the risk estimate, of the investment, that the investor makes. There are different categories of risk which can be linked to the operational activities, competition, regulatory (important to be compliant) and economic conditions. In the context of waste heat recovery in particular, the operational activities can encompass risks: the risk of getting lower volumes at other temperatures than expected are frequent examples. In terms of competition, there are other alternatives to provide heat on the market pushing the waste heat recovery to be cost efficient. In terms of regulatory readiness there is still no explicit laws addressing how to consider waste heat: is it comparable to a RES? Is it something else? This uncertainty creates risk in waste heat recovery investments in that there are no standardized solutions to apply. On the economic side, the very important relationship with the waste heat provider has been addressed by many. There is a need for an understanding of each other's processes and a will to engage in long term contracts. A risk-free investment is an investment that renders the expected return. In real life, there is no such thing as a risk-free investment as even the most stable securities like national debt bills are linked to the risk of the nation going bankrupt, which can happen even if it is rare. Depending on the characteristics of an investments, an investor will assess the necessary risk premium for undertaking the investment (e.g. the necessary reimbursement for the investor to assume the risk of the investment).

Waste heat recovery investment characteristics

An investment is realized if it is assumed to generate a value in the future and if the estimated level is at pair with the investors' appetite for risk. An investment can be characterized in different ways where common parameters are [3]:

(i) the size of the investment,
(ii) the intent of the investment,
(iii) the kind of resource invested in, and
(iv) the connections between investments.

The size of the investment is important in terms of the risk associated with it since a smaller investment is often seen as less risky than a large one even though, as shown in [1] the opposite can be true for waste heat recovery collaborations. The intent of the investment will also impact the riskiness of it. A replacement investment, for example, will ensure capacity in an ongoing business whereas an investment in R&D or in something outside of the core business tends to be associated with greater risk. Waste heat recovery investments tend to fall in the latter category making them either riskier than investments in the core business, or simply less prioritized (for example, it is more important to a computer center to operate its IT equipment than recovering the heat from its cooling process). The kind of resource invested in will also impact the risk associated with the investment: if

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the investment covers some fixed assets (machinery, land, storage) it is associated with an inherent value that is written off over time whereas an investment in a new technology or in securities is a more risky investment. Waste heat is associated with a process that generates heat and to a demand of heat or cooling. Hence, it will be available as long as the process itself is in place or the demand remaining making the discussion of industrial closure an important risk to consider in such an investment. With regard to the connections between investments they can be independent (there is no impact on the cash flows between the two), dependent or mutually exclusive (e.g. if one investment is undertaken the investment alternative is made obsolete). In the context of waste heat recovery an investment in a process reducing waste heat significantly would be mutually exclusive with an investment in waste heat recovery.

There are business risks associated with any investment (competing alternatives, policy arrangements incentivizing certain solutions over others, technological development, fixed costs and variable cost drivers (like price of raw materials or fuels) and there is always a cognitive bias in the assessment of the riskiness of an investment.

2.1 Risk for terminated cooperation and risk aspects derived from barriers to cooperation

The low volumes recovered in Europe today, in spite of promising characteristics reveal that barriers are present for greater utilization of waste heat. One identified barrier is the risk that industries with excess heat can terminate their activities, resulting in the loss of heat recovery. Excess heat recovery investments are therefore sometimes rejected, despite them being viable investments. The risk of termination of industrial activities has been assessed by a study of 107 excess heat recoveries in Sweden [1]. The analysis verified that terminated industrial activities are one of two major explanations for terminated heat delivery. The other major reason is substitution by another heat supply. These two explanations correspond to approximately 6 % of all annual average heat recoveries. The identified risk factors are small annual heat recovery and the use of heat pumps when low-temperature heat was recovered. The main conclusion is that a small proportion of industrial heat recovery has been lost in Sweden because of terminated industrial activities. Indeed, identified in the Lygnerud and Werner paper, the combination of longer operational years, lower proportions of lost heat volumes, and the scale effect of lower supply costs for large-volume cooperation provides a motivating argument for allocating a lower risk premium to large-scale industrial excess heat recovery cooperation, compared to small cooperation: an information that is important to future investors in waste heat recovery.

To summarise, one of the main risks identified is industrial closure terminating the waste heat recovery. In the study of waste heat recovery investments in Sweden 1974-2014 [1], the risk of premature termination showed to relate to the following risk aspects:

- **Absence of district heating network** making the recovery limited to a local area.
- **Cost competitive heating alternatives**.
- **Policy incentives for other forms of heat supply** like bio or waste fueled combined heat and power (CHP) plats.

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- **Lack of technical know-how**.
- **Asymmetric information** between waste heat provider and district heating operator on each other's processes.
- **Cognitive bias of the value of the heat**, i.e. the waste heat provider tends to overestimate the value of the waste heat.
- **Substituted with other heat supply** – The district heating (DH) company invested in other heat supply.
- The most discussed risk of them all - the **risk of the industrial activity closing its waste heat generating activity down**- either the industry is closed down or the heat is used internally instead of delivered externally.

Some of the risk aspects may influence each other, e.g. the absence of a district heating network may relate to lack of technical know-how.

In addition to the risk of premature termination of an excess heat collaboration, there are several other business risks related to investing in waste heat recovery. For example, there is risk of increased costs or decreased income due to technical complications and collaboration issues. Based on the barriers that were identified in SO WHAT D3.1 "Report on current barriers to industrial WH/C recovery and exploitation" [4], the following risk aspects have been derived:

- **Uncertainty in the legal framework and policy.** If the legal framework and policy does not cover industrial waste heat, nor district heating or cooling networks, there is a risk for the investment. For example, there is risk of long permission processes, and uncertain outcome, for piping. Also, if industrial waste heat is not promoted by policy, there is risk that other energy sources get an advantage.
- **Lack of technical know-how.** If the technology for valorisation of industrial excess heat is new in the country, it may be difficult to find the technical know-how for installation and operation. This implies a risk of technical complications and delays of installations.
- **Difficulty to agree on price.** If price discussions have been difficult in the initial phase, there could be an increased risk of continues difficulties at renegotiation of the contract. In worst case, this may even lead to termination of the cooperation.
- **Unpredictable heat flow.** An unreliable flow of heat involves risk for unexpected costs. For example, back-up boilers with more expensive fuel use may be needed to use more or inconveniences for the end-costumers may occur which may jeopardise the costumer relations.
- **Waste heat recovery is not a core business**. If heat recovery is far from the core business, there is a risk that dealing with collaboration issues will have low priority for the management.
- **The heat source the only/main one**. This could involve risk of large disruption for the heat costumers at industrial production stops which may jeopardise the costumer relations. With several heat sources, there may be greater possibility to cover up if one source is temporarily failing.

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2.2 Risk assessment

The classic definition of risk [5] is that it is an event with a known likelihood. To make a risk assessment the likelihood of the event is multiplied with its consequence and a risk score is defined [6]. Depending on the purpose of the risk analysis the assessment needs to be more or less detailed. If, for example, the analysis is done to mitigate operational errors in a very important process in an industry the level of detail of the analysis needs to be very high. In this case, the objective is to attempt to add new knowledge on the riskiness of waste heat recoveries allowing a less detailed analysis to be undertaken. The assessment can be based on observations of frequencies of an event allowing a quantitative analysis or it can be based on qualitative assessments. In this report, identified risks from literature are addressed by means of interviews and research on terminated Swedish waste heat collaborations, i.e. a qualitative approach.

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3 Methodology

The point of departure for the business risk evaluation of waste heat and cold exploitation was key risk aspects based on Swedish data [1] on risk for termination of waste heat recovery collaborations[2]. A unique study was made for all Swedish waste heat recovery collaborations between 1974 - 2014 to identify risk factors for waste heat recovery investments [1]. In the following, the methodology of this SO WHAT deliverable is described step by step.

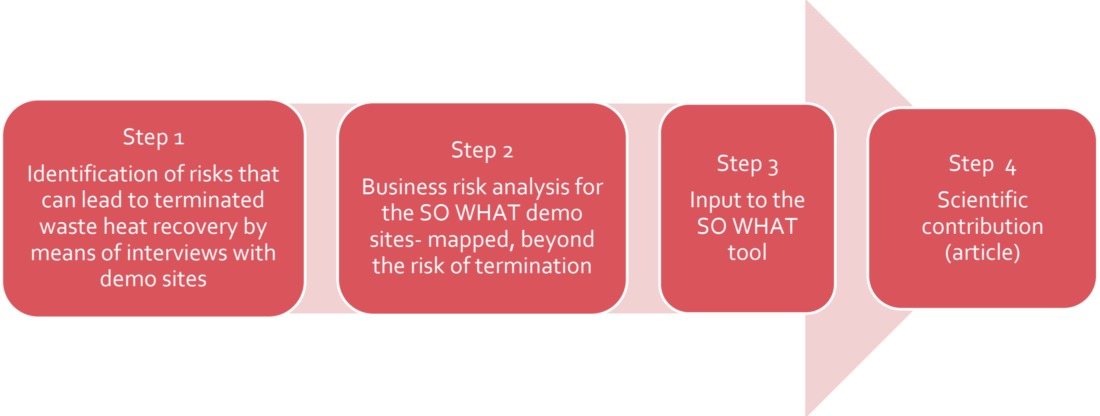

Figure 1 Methodology described step by step.

Step 1: Identification of risks that can lead to terminated waste heat recovery by means of interviews with demo sites. In this task, new knowledge is generated on the risk of industrial closure based on Swedish data (complementary data was gathered for the collaboration sites that were not covered by the aforementioned paper). Also, new knowledge on the risk of industrial closure of the industrial sites of SO WHAT is identified and additional risks that are of relevance to the industrial WH/C recovery investment are mapped for the demo sites of SO WHAT. To collect the data, interviews with the demo sites regarding their perceived risks started in January 2020. To prepare interviews with the demo sites a questionnaire (see Appendix A. Questionnaire) regarding risks related to excess heat recovery was compiled based on the knowledge from [1]. The questionnaire was validated by the Swedish Lighthouse cluster in December 2019. The semi structured questionnaire included questions concerning several deliverables in the SO WHAT project (costs and benefits, barriers, contractual arrangement and risks).

Step 2: Business risk analysis for the SO WHAT demo sites- mapped, beyond the risk of termination. The second step was to analyse the risk picture for each SO WHAT demo site and to map it per site. In the business risk analysis the documentation from interviews together with an industry analysis for each branch of the SO WHAT demo sites (see Appendix B. Analysis of risk for industrial closure) was studied and assessed for the following identified key risk factors:

- Updated industrial processes removing the waste heat/cold generating process

[2] Sweden has a history of recovering excess heat from industries to a larger than in other parts of Europe and has therefore been subject to previous studies regarding risks. A Swedish study from 2018 analysed most of the industrial heat recoveries to district heating systems in Sweden between 1974-2014 to quantify the risk of terminated cooperation and to identify the difference in characteristics between terminated and on-going cooperation's. 109 cases of industrial excess heat recovery in Sweden were identified and 107 of which could be analysed. 74 collaborations were still in operation in 2014 and 33 had terminated.

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- Technical issues with heat pump
- Internal use of the heat/cold instead of selling it
- Small heat/cold volumes
- The industrial activity ceases
- The heat/cold receiver invests in other solution
- Unclear regulations
- Lack of technical know-how
- Difficulty to agree on price
- Unpredictable heat/cold supply
- Energy is not a core business, and
- The waste heat/cold is the only or main source of heat/cold.

A risk heat map for each of the demo sites focusing om WH/C collaboration was compiled by analyzing the Likelihood (1-5), the Consequence (1-5) and scores for each risk factor (Likelihood × Consequence) was calculated, according to Figure 2.

		Consequence				
		Very small (1)	**Small (2)**	**Medium (3)**	**Large (4)**	**Very large (5)**
Likelihood	**Very large (5)**	Moderate (5)	High (10)	High (15)	Catastrophic (20)	Catastrophic (25)
	Large (4)	Moderate (4)	Moderate (8)	High (12)	Catastrophic (16)	Catastrophic (20)
	Medium (3)	Low (3)	Moderate (6)	Moderate (9)	High (12)	High (15)
	Small (2)	Low (2)	Moderate (4)	Moderate (6)	Moderate (8)	High (10)
	Very small (1)	Low (1)	Low (2)	Low (3)	Moderate (4)	Moderate (5)

Figure 2 Risk heat map categories

The results of the demo sites are illustrated and compared with web diagrams (see example in Figure 3). An additional overall assessment of the impact of integrating fluctuating RES with WH/C on the key risk factors mentioned above was performed and presented. Basis for the analysis was the RES alternatives which were developed during autumn 2020 for the cost-benefit analysis (CBA) in the SO WHAT D3.2 "Report on the CBA of industrial waste heat and cold and RES in industry investments in Europe " [7].

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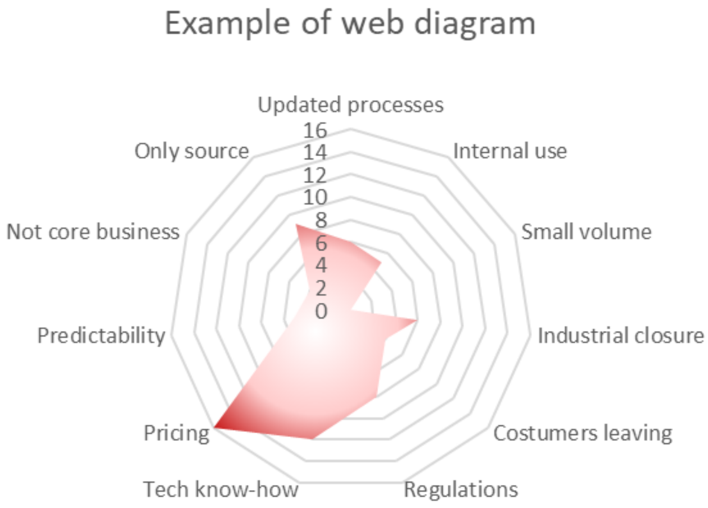

Figure 3 Example of web diagram presenting risk heat map scores for a demo site

Step 3: Input to the SO WHAT tool. Based on the conclusions in this report, a suggestion on how to include business risk assessment and risk mitigation into the SO WHAT tool is presented. The tool is an integrated software which will support industries and energy utilities in selecting, simulating and comparing alternative industrial excess heat (IEH) and cold exploitation technologies

Step 4: Scientific contribution (article). The last step is to make a scientific contribution developing existing research on the Swedish situation. In the original article by Lygnerud and Werner (2018) [1] it is pointed out that the recovery of industrial excess heat for use in district heating systems can be characterized by great political interest, high potential due to low utilization and often high profitability.

Prior to the article mentioned above, no scientific information was available on how high the termination risk is, or why the transfer of recovered excess heat into district heating systems is terminated. Consequently, the risk premium in investment assessments tends to be overestimated in feasibility studies and sometimes stopping an investment that could be profitable. In step 4, the reason for terminated waste heat recovery activity for the 33 cases where such information was lacking in the Lygnerud and Werner article (2018) [1] have been identified developing the existing research on the Swedish waste heat recovery situation. To this information, new knowledge on risks characterizing potential waste heat recovery investments is added (from the SO WHAT sites) providing an updated risk profile for waste heat recovery investments, allowing for increased accuracy of profitability calculations made for investment decisions. The results from the risk analysis in SO WHAT are summarized in an updating, manuscript that will be sent to a journal for peer-review.

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4 Risks of waste heat collaborations terminating based on Swedish data

Sweden has a history of recovering waste heat from industries to a larger extent than other European countries. In an article from 2018 [1], most of the industrial waste heat recoveries in Sweden between 1974-2014 were analysed. 109 cases of industrial waste heat recovery were identified and 107 could be analysed. 74 collaborations were still in operation in 2014 and 33 had terminated. The focus in the study was to identify risk factors in industrial waste heat collaboration that resulted in termination of the collaboration. Two main risk factors were identified; the size of the energy delivered (Large >83.3 GWh/year, 83.3 GWh/year>Medium>15.3GWh/year and small<15.3GWh/year) and whether the heat recovery required a heat pump (due to the temperature of the waste heat being too low). Small volumes of delivered heat and the necessity of a heat pump were found to increase the risk of waste heat collaboration terminating. Industries that can deliver large volumes of waste heat at high temperature make for a lower risk of collaboration terminating.

In [1] six out of the 33 terminated collaborations had terminated due to unknown reasons. The previously unrecorded cases of terminated industrial waste heat collaborations in Sweden have now been uncovered and are able to provide additional information on risk factors (Table 1).

Table 1: New findings on reasons for terminated waste heat collaboration in Sweden

Collaboration	Reason for terminated collaboration	Industry	Operational years	Size of heat delivery	Heat pump
1	Unknown	Metal products	7	Small	N
2	Technical problems- technical issues with the HP	Metal products	20	Small	Y
3	Process change- the heat is utilized internally at the industrial site	Machinery	9	Small	N
4	Substituted with other heat supply- The DH company invested in other heat supply	Pharmaceutical	7	Medium	N
5	Process change- The process that previously delivered excess heat changed	Metal products	7	Small	Y
6	Terminated industrial activity	Pharmaceutical	6	Small	N

Out of the 33 terminated collaborations in Sweden, knowledge about why the collaboration was terminated is now available for 32 out of a total 33 sites. The last unknown is a collaboration that was active between 1984-1990 where both the industrial partner and the DH company has transferred ownership and the records have been lost. The industrial partner was still in operation some years after 1990 and hence the collaboration did not end due to industrial close-down. For the other six previously unrecorded collaborations, one ended due to technical issues with the HP, one due to the DH company investing in other heat sources, one due to industrial closure and two due to the industry partner changing its processes, either to utilize the heat internally or the process that generated heat

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was removed. The finding in [1], that a heat pump is always included in collaborations ending due to technical problems is confirmed by the case with technical problems. The case with terminated industrial activity was a collaboration with small volumes and no heat pump (HP) which was found common in previous results. In [1] it was found that the DH company was more likely to invest in other heat supply when a HP was included in the collaboration, here it is identified a case that contradicts previous findings as the delivery was of medium size and did not include a HP but was still substituted with other heat supply. The aspect of collaboration ending due to process changes in the industry is a new aspect that had not previously been identified.

A summary of reasons for collaboration terminating, divided by industrial sector, for the 33 terminated Swedish collaborations is summarized in Figure 4. Terminated industrial activities is the most common cause of terminated cooperation in Sweden. The other main reason is the substitution with other heat supply in the heat network.

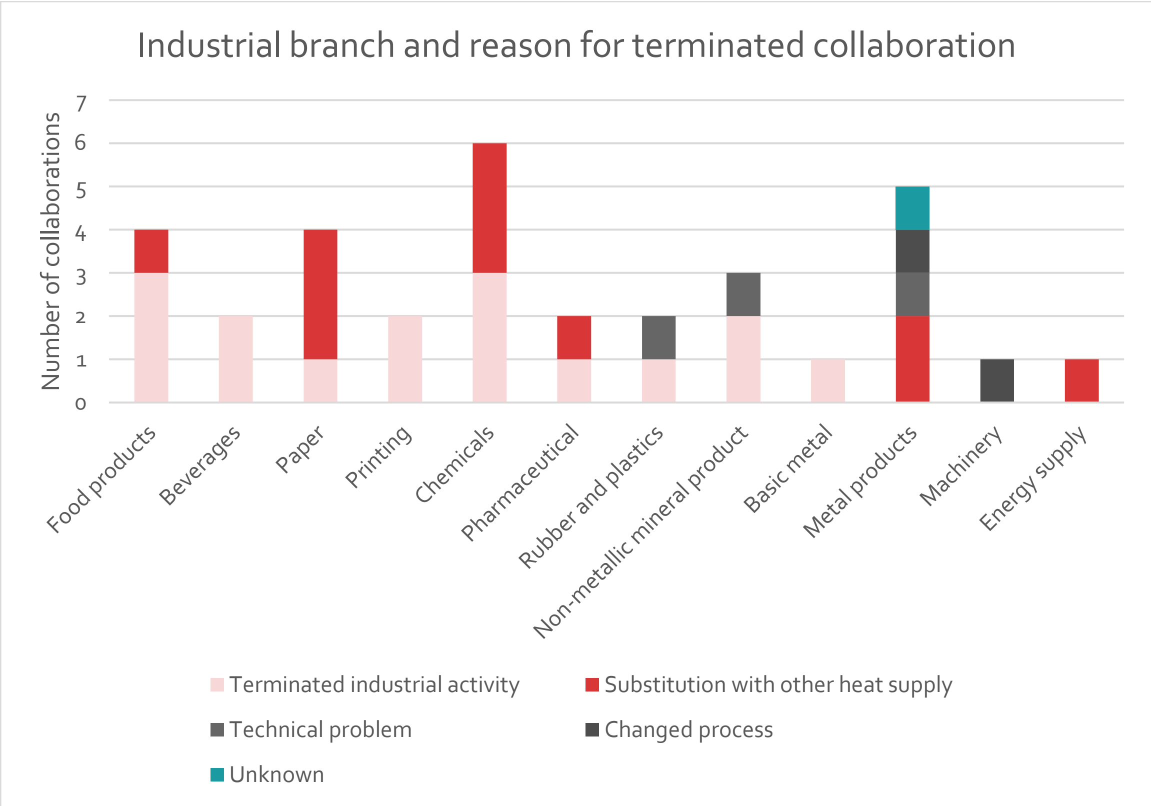

Figure 4: Industrial branch and reason for terminated collaboration

The reason for terminating the collaboration can be the decision of the industry, from the receiving partner, or both and the risk if viewed differently depending on who can control it.

Risks for the partner receiving the heat:

- Terminated industrial activity
  - The industry shuts down or relocates
- Industry changing its processes
  - Starts utilizing the heat internally

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- Process delivering waste heat is removed or altered

"The collaboration was terminated because the industrial partner started utilizing the waste heat internally"[3]

Risks for the partner supplying the heat:

- Substitution with other heat supply
  - Receiver of heat invests in other production plant

"The district heating company built a new boiler which was the reason the delivery was terminated, there was no longer a demand"[4]

Risks for both partners:

- Technical problems
  - For example, with the heat pump

Small volume heat deliveries and the necessity of heat pumps are the main risk factors for terminated waste heat collaboration in Sweden [1]. In Figure 5 these risk factors have been highlighted for all known industrial waste heat collaborations in Sweden (107 in total). Most commonly industrial waste heat collaborations do not include a HP. No collaborations with large volume heat delivery have been terminated whereas small volume heat delivery have terminated in almost half of the collaborations.

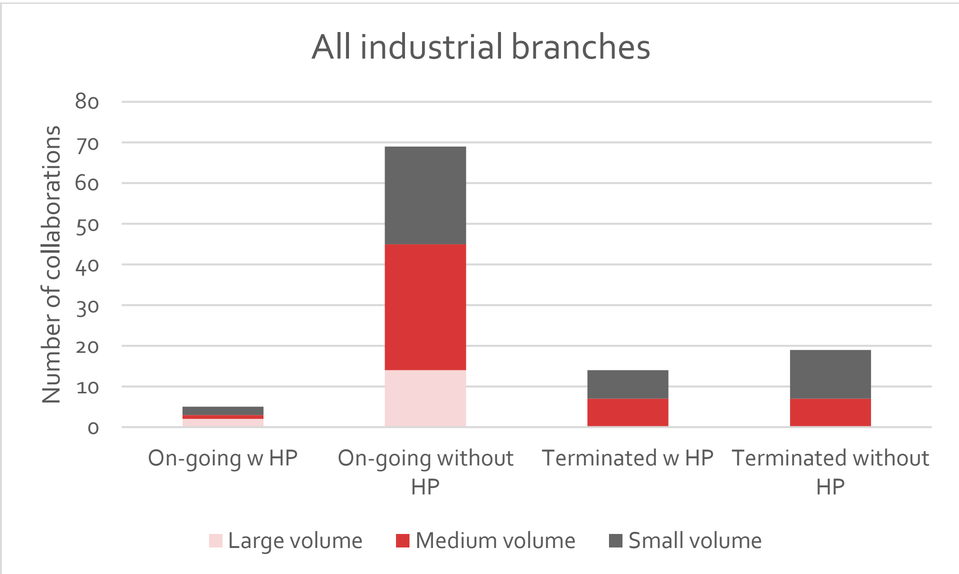

Figure 5 Highlighting two known risk factors of waste heat collaboration among all known industrial waste heat collaborations in Sweden; HPs and volume of heat

[3] Original quote from one of the respondents: "*Samarbetet med industripartnern lades ned eftersom industripartnern själva började återvinna energin internt*."

[4] Original quote from one of the respondents: *"Fjärrvärmeföretaget byggde en ny panna och det var anledningen till att leveransen slutade, behovet fanns inte"*

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By specifically looking at the known collaborations in Sweden for the industrial branches in the SO WHAT demo sites, and highlighting the known risk factors in the data, the knowledge from Sweden can be included in the risk analysis for the SO WHAT demo sites. For some industrial branches few known cases are available, and conclusions derived from the data are more uncertain.

4.1 Pulp & paper

27 collaborations of waste heat from the pulp and paper industry are known in Sweden. 23 cases are still on-going, in all sizes of volume but mainly without a HP. Four cases are terminated. Both cases with a HP were terminated due to substitution with other heat supply, as well as a medium volume without HP. The small delivery without HP ended due to terminated industrial activity. In SO WHAT the Spanish demo site Ence Navia belong to the Pulp & paper industrial category. Ence Navia does not foresee the need for a HP to enable the collaboration and the annual average heat delivery is expected to be almost 90 GWh which classifies as a large volume delivery. Based on the Swedish experience with Pulp & paper waste heat collaborations the demo site Ence Navia is at low risk.

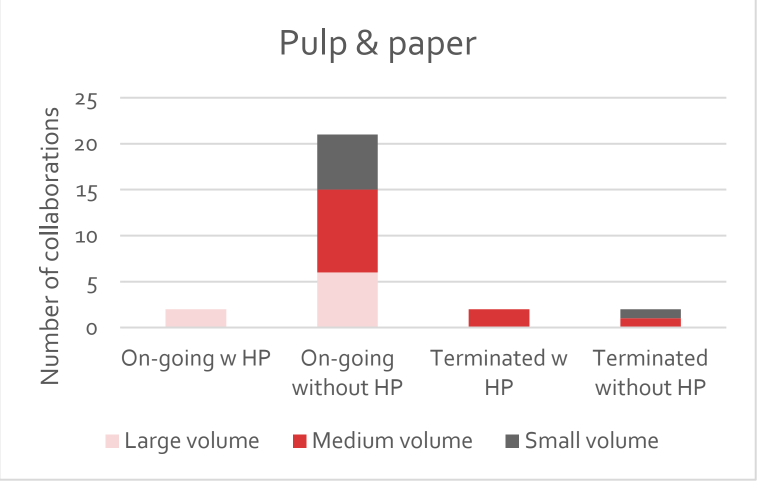

Figure 6: Waste heat collaborations in the industrial category: Pulp & paper

4.2 Coke and refined petroleum

All five Swedish collaboration in the Coke and refined petroleum branch are on-going. The collaborations are medium to large volumes and do not include a HP. This indicate a low risk for heat collaboration with this sector. In SO WHAT the Romanian demo site Petromidia refinery belongs to this category, however currently there is no plan for external collaborations as all heat will be utilized internally.

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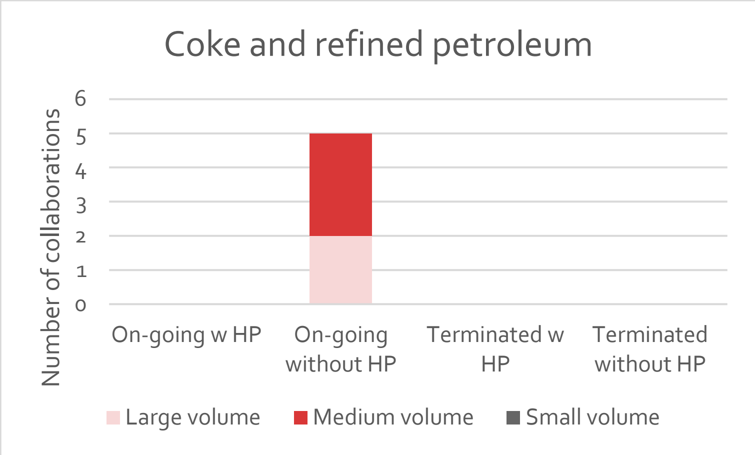

Figure 7: Waste heat collaborations in the industrial category: Coke and refined petroleum

4.3 Chemicals

There are 14 known collaborations within the chemical industry in Sweden. Most collaborations are medium volume. Three out of four teminated collaboration that included a HP closed due to substitution with another heat supply. The remaining three due to terminated industrial activity. In SO WHAT the Belgium demo site IMERYS goes under this category. The IMERYS demo site does not foresee to include a HP in the waste heat collaboration and the expected average annual heat delivery is 16.7 GWh which categorises as a medium volume delivery (the limit to be classified as a small volume delivery is 15.3 GWh). Based on the Swedish experience in the Chemical branch most of the collaborations (both small and medium volume) that did not include a HP have not terminated and the demo site is therefore categorised as low risk.

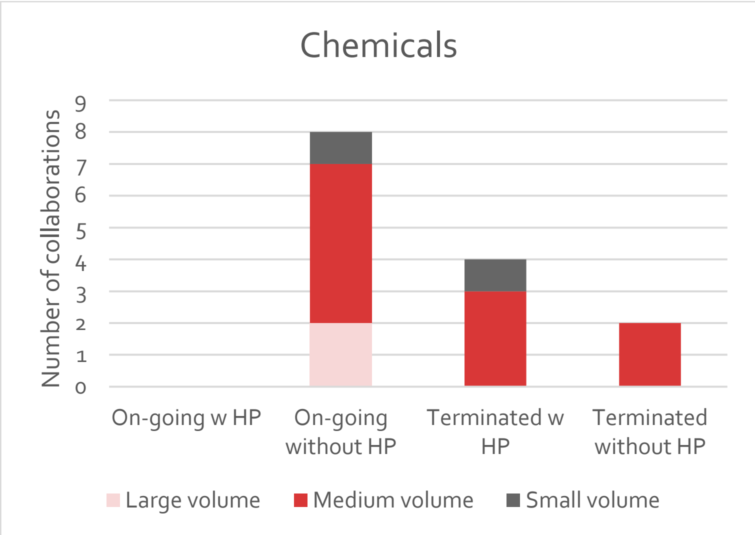

Figure 8: Waste heat collaborations in the industrial category: Chemicals

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4.4 Waste management

Combustion of waste to produce both heat and power is common in Sweden, however, this is generally not considered as waste heat but rather co-production. Two cases were included in the dataset, both are on-going and did not include a HP. In SO WHAT two demo sites are categories as waste management: LIPOR Maia in Portugal and ISVAG in Belgium. Neither LIPOR Maia or ISVAG will have a HP and the size of heat delivery for ISVAG is almost 40 GWh (medium volume) and not known for LIPOR Maia, hence the risk indicates to be low at these sites.

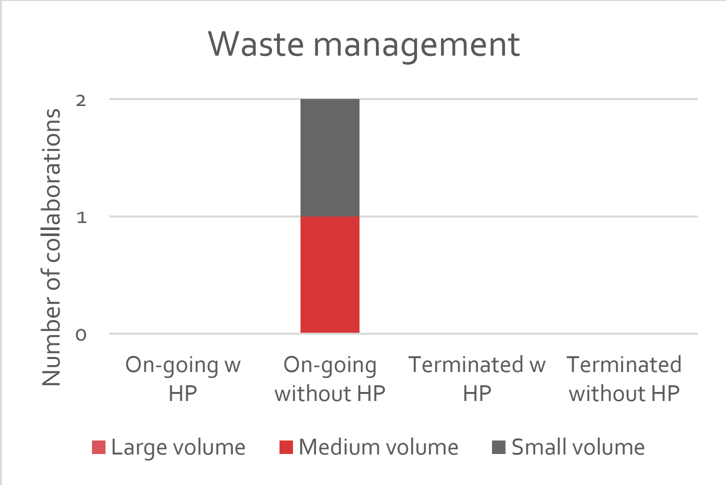

Figure 9: Waste heat collaborations in the industrial category: Waste management

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5 Risks related to the SO WHAT demo sites

This chapter describes the perceived risks of the SO WHAT demo sites regarding WH/C collaboration in accordance with interviews completed in January and February 2020. New knowledge is generated on the risk of industrial closure of the industrial sites of SO WHAT, together with mapping of additional risks that are of relevance to the industrial WH/C recovery investment. The interview questions related to additional risks of the WH/C collaboration ending focused on a) reduced WH/C availability, b) WH/C end user choosing other heat supply, and c) the volume of heat delivery. The mapping of the additional risks then involved the following issues: i) Volume of heat supply; ii) use of heat pump; iii) amount of heat suppliers; iv) financial support schemes and; v) competitive heat alternatives. Representatives from four of the nine SO WHAT demo sites were interviewed. Table 2 presents the respondents which have been interviewed. Three of the SO WHAT demo sites - UMICORE (BE), Petromidia (RO) and M&R (IT) - are focusing on internal heat recovery and are thereby not applicable for the study. Regarding MPI (UK) the demo site is not yet decided and will not be part of this analysis. The demo site RADET (RO) will also be excluded since the industrial partner for the excess heat collaboration was not chosen at the time of this analysis.

Table 2 Interview respondents of the demo sites

Country	Demo site	Respondent
Belgium	ISVAG and IMERYS	Kelvin Solutions
Spain	ENCE	Cartif and Eleukon
Portugal	LIPOR	2GoOut

The interview questions given to the demo sites are presented in Appendix A. Questionnaire. Each demo site is introduced with a short description of the site (more details are presented in D3.1 [4]) and risk analysis of the relevant industry. The full text industrial analysis is attached in Appendix B. Analysis of risk for industrial closure.

5.1 Antwerp, Belgium (ISVAG) – Waste to energy plant

5.1.1 Description of demo site

The Wasteto-Energy (WtE) plant ISVAG is located close to the city of Antwerp, is owned by several municipalities and has previously only produced electricity. The incineration of the residual household waste takes place in a grate furnace. In the SO WHAT-project ISVAG wants to explore the potential for using waste heat and expand the grid by selling and distribution the heat from the waste incineration. Different studies have been carried out related to the use of heat: a feasibility study for a small scale district heating grid (3 MW), a feasibility study for a large scale district heating grid (>40 MW), design for the heat use (3 MW) in the existing plan and finally to design a new WtE plant.

The first step for ISVAG is the construction of a small scale district heating network powered with heat from the existing WtE plant. Discussions held between ISVAG and a logistics company have resulted in that the logistics company now is connected and receives heat from the plant. Feasibility studies are performed regarding the possibilities to expand the grid to the surrounding cluster of small companies (beverage etc). ISVAG is also planning to scale up the heat production and at a later

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stage expand the heat network to Antwerp. Other incentives for ISVAG to WH/C collaboration is the environmental permit and to contribute to lower CO_2 emissions(5).

Table 3 Description of site in Antwerp

Name, Partner	Location	Sector	Process	Temperature
ISVAG Incineration (KELVIN)	Antwerp (Belgium)	Waste to Energy	ISVAG superheated stream power plant valorise via incineration local wastes and WH from the boilers.	400 °C

5.1.2 Risks to WH/C collaboration

ISVAG is conducting initial discussions with several external partners in the vicinity of the waste incineration plant. The long-term goal is to expand the heat network to the city of Antwerp Discussions with a logistics company (warehouse type) have reached furthest and the risk questions were answered with a focus towards that specific collaboration, but many answers can also be considered general for other collaborations.

5.1.2.1 Risk of industrial closure

According to Appendix B. Analysis of risk for industrial closure, solid waste management is mainly a local responsibility that is either operated by local public entities directly, or through mixed public-private entities. In the EU waste disposal segment (e.g. landfills and waste incinerators) operate in a somewhat competitive market but are still restricted by their assigned territorial area. Around one third of the municipal solid waste is treated by waste-to-energy, and the share has increased with EU targets for decreasing the share sent to landfills. Belgium is among the top performers and there are limited opportunities for new waste incinerators. The already existing plants will be of no shortage in waste supply in a foreseeable future.

Currently ISVAG consider the risk of the WH collaboration ending due to termination of the industrial activity as low. However, the upcoming renewal of the environmental permits may lead to uncertainties for further operation, but the excess heat collaboration may reduce this potential risk. A new WtE-plant is currently being built and it may be more likely for other waste incineration plants to close before ISVAG. The present end user (the logistics company) still has their own boiler connected to the heat grid but are planning to close it. If doing so, the end user will be fully dependent on ISVAG delivering the heat to the network. ISVAG do not consider that the collaboration will impact the competitiveness of the industry since ISVAG is a cooperation between different municipalities without competition.

Table 4 Summary of industry analysis for ISVAG

Demo site	Industry	Country	Risk
ISVAG	Waste to Energy	Belgium	Low

5.1.2.2 Additional risks of relevance

Table 5 presents the input given by ISVAG to the interview questions regarding the risk of the WH/C collaboration ending due to reduced WH/C availability, WH/C user choosing other heat supply and the volume of heat delivery.

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Table 5 Additional risks of relevance ISVAG

Risk of WH/C collaboration ending due to…	Input from demo site
…reduced WH/C availability	
To what extent is this considered a risk?	Considered as medium risk due to ISVAGs environmental permit is getting renewed. A decrease in waste volumes in the future might reduce the available excess heat from the incineration plant. The government policy on waste might lead to decreased availability within 5-10 years. The new plant which will replace the current one is likely to have less excess heat while incinerating larger volumes of waste. If investments are made in the heat grid, the recovered heat from the WtE plant will be an alternative of interest and more likely close other sites.
…WH/C user choosing other heat supply	
Need of heat pump to enable WH/C recovery?	No.
Risk for the collaboration if a heat pump is used?	No. The electricity price is high in Belgium, but in a case of using a heat pump ISVAG could use their own produced electricity for it.
How predictable is the availability of the WH/C?	The predictability of the available waste heat is high, there is a continuous flow in the WtE plant. It is important that the supply is predictable.
Considered on how to keep back-up heat supply?	In the first phase the end users (logistics company) want to keep their existing boiler as backup. For the future they are looking into different centralized possibilities for backup at the ISVAG site or the deliverer. It is also possible that the customer could keep the back-up at their site, not yet decided.
How dependent will the user be on a single WH/C deliverer?	The grid will be completely dependent on ISVAG, but customers have their own boilers today as backup. In second stage, if boilers are replaced by energy from the grid, the end users will be fully dependent on ISVAG.
What heat or cold sources are being promoted in policy and regulations?	Funds are available in heat projects that reduce CO_2 emissions. This is a general support mechanism and not directed towards waste heat.
…the volume of heat delivery	
To what extent is the volume of heat or cold delivery considered imposing a risk?	Today the volume is low and only one customer. When the grid is in place the volume will be bigger and very important. A lot of users will be connected to the grid. When the volume is larger and no other suppliers, the risk gets higher.

5.2 Willebroek, Belgium (IMERYS) – Chemical manufacturing

5.2.1 Description of demo site

IMERYS carbon black and graphite manufacturing center is located in Willebroek (Belgium). IMERYS is the world leader in high-tech, high performance solutions based on specialized graphite and carbons. The industrial site of Willebroek Noord is in the direct vicinity of the industrial site of Puurs and the municipality of Willebroek with its own residential development projects. This offers an opportunity to valorise IMERYS excess heat to industrial consumers, public buildings and residential consumers. Considering that today almost no heat is recovered, a district heating network would make the site significantly more sustainable and futureproof. During the process of Carbon Black, a mixture of H_2 and CO is formed which is currently burned in a furnace and no heat is recovered of the

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max total of 30 MW. The production is 24/7, creating a continuous flow of waste heat at about 600 °C, available from the chimney gases of the furnaces. In order to valorise the waste gas stream, a study has been performed looking into different industrial options ranging from electricity production, over carbon valorisation via the production of chemicals, to heating circuits. This study will be used in SO WHAT as a benchmark for what it concerns both the techno-economic solution proposed and the necessary time and effort.

Currently there are no existing WH/C collaborations in the demo site region. A feasibility study regarding possible heat consumers located in the area and economic evaluation, conducted by the municipality as a part of SO WHAT, is in the final stage. The next step is to discuss potential heat users around IMERYS and investigate the cost of a possible heat grid that could be constructed. IMERYS is interested to assess the best options to use the excess heat and the impact of their environmental permit. IMERYS is also motivated to contribute and reduce the CO_2 emissions of the collaboration partners.

Table 6 Description of site in Willebroek

Name, Partner	Location	Sector	Process	Temperature
IMERYS Carbon black manufacturing (KELVIN)	Willebroek (Belgium)	Chemical manufacturing	IMERYS manufactures Carbon Black producing a mixture of H_2 and CO as by-product which is currently burned in a furnace whose excess heat could be recovered.	600 °C

5.2.2 Risks to WH/C collaboration

IMERYS has performed a feasibility study to assess what potential heat users are in the area and more studies are needed to see what is economically viable. Since no specific partner has been discussed at this point in the project the answers to the questions on risks are for a general collaboration.

5.2.2.1 Risk of industrial closure

According to Appendix B. Analysis of risk for industrial closure, the Asia Pacific region is dominating the global market for carbon black, both in terms of consumption and production. The industry is dependent on the development of the tyre and automotive industry as most of the carbon black produced is used in tyres. The demand for carbon black is strong and prices are slightly increasing. IMERYS specialty products, used for example in Li-ion batteries, produced in Willebroek are experiencing an increasing demand as well.

IMERYS consider the risk to shut down as low, the industrial business is looking to expand the current site. Regarding if the collaboration will the impact the competitiveness of the industry, the respondent considers the possible extra revenue stream.

Table 7 Summary of industry analysis for IMERYS

Demo site	Industry	Country	Risk
IMERYS	Carbon Black	Belgium	Low

5.2.2.2 Additional risks of relevance

In Table 8 the additional risks of relevance to the IMERYS site are presented.

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Table 8 Additional risks of relevance IMERYS

Risk of WH/C collaboration ending due to...	Input from demo site
...reduced WH/C availability	
To what extent is this considered a risk?	This risk is considered quite low, due to that IMERYS is planning to expand the current site. The industry has large volumes of available waste heat that cannot be utilized within the site.
...WH/C user choosing other heat supply	
Need of heat pump to enable WH/C recovery?	No, the waste heat temperature is high.
Risk for the collaboration if a heat pump is used?	- (not relevant)
How predictable is the availability of the WH/C?	The industry has high availability and predictability of the waste heat (24/7). IMERYS have planned short shut down periods every three months. The two installed generators are not shut down simultaneously, but the industry can still need some backups.
Considered on how to keep back-up heat supply?	The utility company or end users might need/want to keep boilers. The location of the backup is not yet decided on. There are several possible options (at end user site, a third party or at IMERYS) to choose between depending on the collaboration.
How dependent will the user be on a single WH/C deliverer?	In the first stage IMERYS will be the only supplier of heat to end user, but in the future maybe other companies could connect to the grid as heat suppliers.
What heat or cold sources are being promoted in policy and regulations?	Funds are available in heat projects that reduce CO_2 emissions. This is a general support mechanism and not directed towards waste heat.
...the volume of heat delivery	
To what extent is the volume of heat or cold delivery considered imposing a risk?	No risk for IMERYS, but for the third partner responsible for the delivery of the heat. The business case of the project depends on the required heat volume from the end users.

5.3 Navia, Spain (ENCE) – Pulp mill

5.3.1 Description of demo site

ENCE pulp mill was built in the 1960-70's and was then a government owned plant. ENCE has a production capacity of more than 1,200,000 tons per year of high-quality eucalyptus pulp through its plants in Navia (Asturias) and Pontevedra. ENCE is Spain's leading producer of renewable energy using biomass, with an installed power of 253 MW in biomass. Pulp mills are relevant producer of waste heat. In this framework ENCE has already identified a project, consisting in the heat recovery from bleaching and causticisation stages to exploit it in a biomass dryer.

There is no existing district heating network in the region. The regional government is currently pushing for waste heat recovery. Initial discussions between stakeholders as ENCE factory and energy service companies (ESCO) have been held on high level meetings, but no deeper studies have been performed on the matter. ENCE would like to sell the industrial excess heat, preferable with a third party (such as an ESCO) between them and the heat users. ENCE gave a proposal in the

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beginning of 2019 to give the excess heat away for free if the collaborating company would take responsibility for the pipes etc. An important question to be addressed in a potential collaboration is which party (industry, ESCO, end user or government) will pay for the initial cost.

The incentives for ENCE to join a collaboration, except the revenue of selling heat, is the public opinion and policy demands. In Spain there are controversies about pulp mills partly due to the odour and partly that the white steam from the chimneys can be perceived as pollutant by the public.

Table 9 Description of site in Navia

Name, Partner	Location	Sector	Process	Temperature
ENCE Pulp Mill (ELEUKON/ CARTIF)	Navia (Spain)	Pulp Mill	This is the mill with the largest production capacity belonging to ENCE Group (685 ktons/year) and the most efficient pulp mill on the eucalyptus market in Europe.	40 - 280 °C

5.3.2 Risks to WH/C collaboration

5.3.2.1 Risk of industrial closure

According to Appendix B. Analysis of risk for industrial closure, the pulp and paper industry is experiencing a transformation as the demand is shifting away from graphic paper to higher-growth areas such as tissue paper and packaging. The global forest-products market has experienced volatility lately but is now expected to reach a stabilization of supply and demand. The demand is forecasted to grow in the long run and China has a significant impact on the market given their large share of the global demand for paper and board products. The forest supply is a constraining factor for new supply capacity, and the cost of wood determines the competitiveness of a pulp mill as the raw material is a large share of the costs. Spanish pulp mills have among the largest wood cost shares in the world, possibly making them vulnerable to changes in price. Currently most of the production of the pulp and paper company is tissue paper for the European market. ENCE has expanded the portfolio by selling by products (electricity, heat, biofuel etc.).

ENCE considers the risk of industrial closure at is as a general concern to some extent in Spain due to the policy changing. The region has a decreasing tendency for industrial activity in the last 20 years. ENCE has had three pulp and paper plants in Spain, one of them closed in 2014 and the production was moved to the remaining two (Navia and Pontevedra). The risk of industrial closure is not deemed probable, but the risk is not negligible for the site. Big investments were recently done at the Navia plant which upgraded and increased the production capacity to 80,000 tons per year. ENCE considers that the collaboration would impact the competitiveness of the industry to some extent, through improved public image and perhaps subsidies (tax reduction from pollutants). Probably ENCE will give away the excess heat for free due to the low price of natural gas, hence the company do not consider the collaboration resulting in a big economic advantage.

Table 10 Summary of industry analysis for ENCE

Demo site	Industry	Country	Risk
ENCE	Pulp & Paper	Spain	Low

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5.3.2.2 Additional risks of relevance

InTable 11 the additional risks of relevance to the ENCE site are presented.

Table 11 Additional risks of relevance ENCE

Risk of WH/C collaboration ending due to…	**Input from demo site**
…reduced WH/C availability	
To what extent is this considered a risk?	Not a big risk. Upgrading of the plant is done. Will not use any more heat internally.
…WH/C user choosing other heat supply	
Need of heat pump to enable WH/C recovery?	No. It depends in the design of the district heating network, someone may need a heat pump. The temperatures from the factory though are 70-90 degrees.
Risk for the collaboration if a heat pump is used?	No. It´s a minor risk since the heat pumps require electricity, which is a cost.
How predictable is the availability of the WH/C?	The WH from the factory is quite predictable, it operates 24 hour per day all around the year, with maintenance once a year. It is a dual business factory, with income from pulp and paper and from selling electricity to the grid. There is always supply of heat due to that the plant has two boilers. Electricity can be produced even when the paper pulp production is stopped.
Considered on how to keep back-up heat supply?	Not necessary. The hospital will keep their natural gas boiler.
How dependent will the user be on a single WH/C deliverer?	Likely only one end user (an ESCO) delivering to end consumers. Probably dependent on only one supplier. The hospital might consider the original natural gas boilers as back up.
What heat or cold sources are being promoted in policy and regulations?	At regional level waste heat is promoted. According to the national regulations, a share of the total hot water demand in buildings must be covered by renewable energy, but industrial waste heat is not considered renewable.
…the volume of heat delivery	
To what extent is the volume of heat or cold delivery considered imposing a risk?	The industry will always consider it as waste heat. It is not a single point of the waste heat, it several points with different temperatures.

5.4 Maia, Portugal (LIPOR) - Waste to energy plant

5.4.1 Description of demo site

The LIPOR waste to energy (WtE) plant located in Maia (Portugal), treating 380,000 tons of waste per year. The WtE plant composed by high temperature gases that go through an energy recovery boiler, which uses the heat to produce steam for power production. Today, LIPOR only sells electricity to the grid. LIPOR has a climate strategy and want to improve efficiency in all operations (recycling, waste incineration, increased heat recovery) and thus improve the profit, which is reinvested in a better service to the community. In 2017 a study was developed concerning the assessment of the technical-economic feasibility of recovery heat of LIPOR's WtE plant and implementation of a district heating system connecting LIPOR and Francisco Sá Carneiro Airport, near LIPOR facilities Oporto. The following different options were considered: additional burning of waste in the boiler, additional

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drawing of turbine steam in medium pressure extraction and heat recovery of the exhaust gas from the boiler. Also, options for district cooling is considered regarding 3 absorption chillers of 4,000 kW of cooling power installed at the Airport.

In the region of the demo site no WH/C cooperation currently exist and in Portugal there is only one district heating system. LIPOR is studying, together with representatives from Oporto Airport and INEGI (Institute of Science and Innovation in Mechanical and Industrial Engineering), related with Oporto University, the possibility to recover the heat and share it. The Oporto Airport is a large consumer of energy and needs heating and cooling all around the year. Before the discussions will continue, assessment will be done on the costs, including investments, operational cost etc. LIPOR also considers collaborations with e.g. the hospital, pools and industries. There is no infrastructure yet, and LIPOR is looking into it with help from third parties and the INEGI.

Table 12 Description of site in Maia

Name, Partner	Location	Sector	Process	Temperature
LIPOR Maia Incineration Plant (LIPOR)	Maia (Portugal)	Waste to Energy	Two incineration lines in a continuous and almost automatic operation burn and treat 380,000 tons/year of municipal waste.	Outlet Flue gases 150 °C Steam to turbine 395 °C Condensates 55 to 60°C

5.4.2 Risks to WH/C collaboration

The risks questions were answered mainly regarding the potential collaboration between LIPOR and the airport as this is the mostly likely collaboration to happen within the SO WHAT project at the time of the interview. Many of the answers are true for any collaboration LIPOR would engage in.

5.4.2.1 Risk of industrial closure

According to Appendix B. Analysis of risk for industrial closure and also described for the Belgian demo site ISVAG in 7.2.1, solid waste management is a mainly a local responsibility that is either operated by local public entities directly, or through mixed public-private entities. In the EU waste disposal segment (e.g. landfills and waste incinerators) operate in a somewhat competitive market but are still restricted by their assigned territorial area. Around one third of the municipal solid waste is treated by waste-to-energy, and the share has increased with EU targets for decreasing the share sent to landfills. Portugal needs to increase its share sent to landfills, meaning that the prospects for waste incinerators are good.

The LIPOR demo site mentions that the waste incineration plant is a monopoly activity and the ownership structure of multiple municipalities makes for a stable long-term operation. The waste incineration sector is not competitive, and the demo site considers that the risk of the industry shutting down is low. The production is stopped approximately one or two days per year, otherwise the operation is continuous. LIPOR considers that a collaboration would have a positive impact on the competitiveness of the industry. Not only in terms of extra revenue but also regarding green image and measures (closing the loop, increased energy efficiency and reducing GHG emissions from operation). This is also in line with LIPORs climate change strategy.

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Table 13 Summary of industry analysis for LIPOR

Demo site	Industry	Country	Risk
LIPOR	Waste to Energy	Portugal	Low

5.4.2.2 Additional risks of relevance

In Table 14 the additional risks of relevance to the LIPOR site are presented.

Table 14 Additional risks of relevance LIPOR

Risk of collaboration ending due to…	Input from demo site
…reduced WH/C availability	
To what extent is this considered a risk?	No risk of reduced burning of waste. The LIPOR region has a low share of waste sent to landfill compared to other Portuguese regions, much is sent to the incineration plant. LIPOR wants to increase the capacity to receive waste from other regions in order to reduce the share of landfills. The government want to reduce waste sent to landfill but does not have funds for incineration plant now.
…WH/C user choosing other heat supply	
Need of heat pump to enable WH/C recovery?	It depends on the temperature required by the end user. Temperature is a critical aspect to be covered in the contracts. Where the heat pump is placed depends on the contractual arrangements (LIPOR or a third party (ESCO)). Perhaps different temperatures will be required for different costumers if the network extends in the future.
Risk for the collaboration if a heat pump is used?	Depends, it is an extra cost, but if the overall investment is good for the user it is not considered a risk.
How predictable is the availability of the WH/C?	The operation is very continuous and stable, the LIPOR plant stops very few times per year. There could be a risk involved with the technology for recovering heat, if it fails the waste heat cannot be supplied. By choosing a mature technology in heat recovery the technology risk can be reduced. It is very important with the predictability of the available industrial WH, both for the supplier and the demand side. LIPOR is a low risk activity, the heat will come from a steady process.
Considered on how to keep back-up heat supply?	Has not been discussed as such. It is very likely, in the collaboration with the airport, that the airport keeps a back-up natural gas boiler given the critical operation of their business.
How dependent will the user be on a single WH/C deliverer?	Fully dependent, LIPOR would be the only supplier for waste heat and cooling to the network.
What heat or cold sources are being promoted in policy and regulations?	Waste heat and cooling sources are not really developed in Portugal, neither in regulation nor in policy. Regulation tends to encourage DH and integration of renewable but there is no clear incentive for waste heat. This is not considered a barrier to implement solution. Solar electricity is promoted in relation to energy communities. Energy communities is where electricity from solar can be shared within a small community. Energy communities as a concept is still in development.

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...the volume of heat delivery	
To what extent is the volume of heat or cold delivery considered imposing a risk?	Large volumes are seen as an opportunity. Small deliveries might lead to less interest by the end-customer. On the other hand, the larger the delivery is the bigger the investment and requirements in contractual arrangement and added complexity.

5.5 Summary of demo sites risks to WH/C collaboration

The respondents have answered the questions from the perspective of the four demo site industries regarding the risks of WH/C collaboration.

- The respondents consider the risk of the industry to close as low.
- The four demo sites estimate that they can contribute with relatively large volumes of excess heat for WH/C collaboration. Generally, large volumes are considered as to be good opportunities but at the same time they involve higher risks than small volumes, e.g. due to larger investments and requirements in contractual arrangement and added complexity. This information is interesting to compare with conclusions from previously studies [1], where a small annual volume of heat recovery was found to be a risk factor of the WH/C collaboration to end. Possibly, this is a matter of *when* the risk is considered. Before the investment is done, the risk is perceived to be higher the larger the investment is, but when it is in place, it is less likely that is terminated if the size is large.
- The demo sites have answered "no" or "maybe" regarding if a heat pump will be used. A general perception is that the heat pump would not entail a risk, but the extra cost for it needs to be considered in the business plan of the collaboration. In previous studies [1] on terminated WH/C collaborations in Sweden, the use of heat pumps when recovering low-temperature heat was identified as a risk factor for premature termination of the cooperation.
- Regarding the four demo sites, the WH/C collaboration would be fully dependent on the single excess heat supplier.
- In Belgium funds are available in heat projects that reduce CO_2 emissions. This is a general support mechanism and not directed towards waste heat. There are no financial support schemes available to the other sites related to excess heat.
- Natural gas is a competing alternative for heating at all of the considered demo site regions [4].

The analysis of the industrial sectors of the demo sites, Appendix B. Analysis of risk for industrial closure, are all considered as being low risk.

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6 Business risk related to

In this chapter, business risks associated to the fluctuating availability deriving from renewable energy sources (RES) production for the SO WHAT demo sites are analysed and estimates of the impact of the RES risk on business model replication (e.g. possibility to replicate the solutions in new places) for the countries of the demo sites are presented. As a first step, the demo sites have described if they considered to integrate fluctuating RES. In the next step, general concepts of integrating fluctuating RES in WH/C collaborating was analysed, followed by a qualitative analysis of the impact of fluctuating RES integration on the business risk in the risk heat map in sub chapter 7.4.

6.1 Fluctuating RES analysis for the SO WHAT demo sites

In the interviews performed, the demo sites answered if they have or plan to have fluctuating RES (e.g. solar thermal, photovoltaics (PV) or wind power) at the industrial site or in the current DH/C network. The following answers were given:

- ISVAG and IMERYS have not considered fluctuating RES integration at the site.
- LIPOR are considering investing in PV in the future, the prerequisites for solar at the site are good. The photovoltaic panels could potentially be used to supply electricity to absorption chillers and/or heat pumps installed at the airport [7].
- ENCE has a combined heat and power (CHP) biomass boiler and the electricity production from the cogeneration is subsidized through feed-in tariffs (additional payment per kWh). The demo site has no plans of investing in solar due to three factors: 1) the value of the feed-in tariff depends on the technology and it is not possible to combine different technologies from one delivery point (e.g. biomass and PV), 2) the conditions for solar thermal in Northern Spain are not considered as good in comparison with central or southern Spain and; 3) the site is not considered to have enough space for installation of solar thermal.

To summarize, at this point LIPOR is the only demo sites which is considering integrating fluctuating RES to the industrial waste heat recovery in a WH/C collaboration. LIPOR is considering installing PV at the industrial demo site and then let the airport use the electricity for heat pumps or absorption chillers at the airport.

In addition, demo sites in the SO WHAT project which are considering fluctuating RES but no WH/C cooperation, are RADET, UMICORE and M&R. RADET is considering integrating solar thermal and biomass in the DHN but it is not related to an industrial site providing excess heat. UMICORE has invested in wind power (13.8 MW) and are considering investing in more (potentially 5.8 MW). M&R has invested in solar thermal (330 kW) and may consider further enlargement of the solar field.

6.2 Theoretical cases of integrating fluctuating RES and WH/C

Since none of the SO WHAT-demo sites at this are point considering integrating fluctuating RES with the WH/C recovery, this chapter will present some hypothetical cases of integrating fluctuating RES and WH/C.

Fluctuating RES (heat or/and electricity) requires the rest of electricity or heat production system to be able to handle ups and downs with respect to the volatility. The larger the share of fluctuating RES the greater the considered impact. With an additional heat or electricity source the risks in the system can be reduced due to diversification of the production mix. The environmental benefits of

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fluctuating RES can strengthen the brand of the company, reduce risk for costumers leaving to and reduce the business risk.

Hypothetical examples of possible combinations of integrating fluctuating RES and WH/C:

- **Heat – Solar thermal.** Solar thermal needs less requirements for rapid regulation of heat production, in comparison with electricity production, due to the district heating network acting as a storage and has an inertia (e.g. it does not get cold immediately if the sun goes in clouds). On the other hand, complementary heat production is required to handle the entire heat capacity requirement, due to less energy production from solar during the winter season. During the summer the solar thermal can also be used to complement WH/C.
  Solar thermal can, depending on the circumstances, be a useful heat source during the winter season. There are examples of with low energy buildings in Sweden fully heated (excluding hot tap water) by stored solar thermal even during a sunny winter day. The mentioned solution has commonly underfloor heating (approx. 30 degrees supply temperature) as an auxiliary heat source at low outdoor temperatures (e.g. minus 10 degrees). Low temperature district heating could be the most relevant system for this application.
- **Electricity – PV.** The volatility of PV can in most cases be handled with a connection to the regional/national power grid, serving enough power when the production is lower than the electricity use. With a connecting to the power grid the risk is not increased when using PV connected to a heat pump. As an option if the power grid owner opposes a connection of the PV plant (due to the volatile character) the system could be complemented with energy storage (e.g. electrical battery or a heat pump producing high-temperature hot water). An example of a related EU-project on the subject is the EU-project SunHorizon [8] which is studying four technology packages with heat pump and solar appliances (PV and thermal) demonstrated at eight demo sites (single family houses, multi-level buildings, municipality owned buildings, sport facilities) in four different EU countries (Germany, Spain, Belgium and Latvia).
- **Electricity – Wind turbines.** Most commonly the electricity produced with wind power turbines is sold and delivered directly to the power grid. In some cases, there are limits in the connections point to the grid resulting in the surplus of electricity becomes unused (wind curtailment). If the wind power electricity production would be used in heat pumps to produce high-temperature hot water (maybe with the storage possibility) connected to district heating the connection between electricity and heat production is possible. This could be relevant at moments with excess production compared with the electricity use and low electricity price.

6.3 Impact of RES on business model replication

According to information on the EU funding and tenders portal on replication market replication means "to support the first (to Europe or a relevant sector) application or market deployment of an innovation which, through already demonstrated, has not yet been applied or deployed on the market owing to market failure or other barriers[5].

[5] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/support/faq;keywords=/1016

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RES are not generated evenly, but are linked to wind and solar conditions for example. Adding a new component to the DH mix, like electricity when operating heat pumps, has been shown to add risk to waste heat recovery investments (Lygnerud & Werner 2018). When drafting the SOWHAT project proposal it was foreseen that the sites would resort to RES in different ways (which is also the case as outlined above). The idea was to assess if the addition of RES to a waste heat recovery arrangement added risk. As it turns out only LIPOR will combine RES with waste heat recovery. The inclusion of PV will not be part of the waste heat recovery scheme but used to supply the airport absorption chillers with electricity. Hence, its inclusion does not add to the risk of the waste heat recovery at all.

We only have one case to comment the impact of RES inclusion in waste heat recovery on risk and business model replicability. Assuming that the RES is a complimentary heat source to a main waste heat recovery it is likely that other risks, than the volatility of RES generation, impacts the replicability of waste heat recovery business models.

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7 Analysis – Risk heat mapping

In this chapter the risk analysis of six of the demo sites is presented. The demo sites chosen for analysis are the sites with plans of heat and/or cold collaboration between an industry and other stakeholders such as a district heating network or great end-users of heat or cold:

- ISVAG (Belgium)
- IMERYS (Belgium)
- ENCE (Spain)
- LIPOR (Portugal)
- GOTE (Sweden)
- VEAB (Sweden)

The five remaining demo sites are not analysed since they only consider internal heat integration within the industry itself or have not yet decided on the collaborating parties.

Based on the data presented in previous chapters and the report D3.1 about barriers to cooperation, the likelihood at each demo site of each risk was estimated on the scale 1-5, where 1 means that there is very small likelihood and 5 means very large likelihood. Then the consequence of each risk, if it should happen, was estimated on the same scale. By multiplying the likelihood and consequence of each risk a risk score is achieved. In the following the estimations are explained and the risk scores are presented in web diagrams for each demo-site.

In Table 1Table 15 the estimated consequences of each risk are quantified and commented. The consequences are assumed to be equally large, independent on case. The exception is the risk of heat/cold receivers investing in other solutions. This consequence of this risk will depend on the number of receivers. If only one or a few receivers, the consequence will be large if they invest in other solutions. But if the receivers are many, the consequence will be smaller.

Table 15 Estimation of consequence for each risk

	Consequence (1-5)	Comment
Updated industrial processes removing the waste heat/cold generating process	5	If the waste heat is totally removed, the consequence is very large for the investment.
Technical issues with heat pump	3	It may be expensive to reinvest in a heat pump. Medium size risk for the collaboration to end if a heat pump is used, according to the Swedish experience.
Internal use of the heat/cold instead of selling it	5	If the waste heat is totally removed, the consequence is very large for the investment.
Small heat/cold volumes	3	Medium size risk for the collaboration to end if the heat volume is small, according to the Swedish experience.
The industrial activity ceases	5	If the industrial activity ceases, the collaboration will end as well.
The heat/cold receiver invests in other solutions	2-4	The consequence will be high if a large part of the heat/cold receivers change to other solutions. Higher value if there are few end users of heat/cold.

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Unclear regulations	3	From a waste heat collaboration perspective, regulations can change both to the better and the worse. Hence, a medium value for the risk.
Lack of technical know-how	3	If technical know-how is difficult to find for the design and construction of the installations, there is a risk that mistakes are being made which will cause extra costs. Or the construction may be delayed if the companies with right competence are engaged elsewhere. A delay may cause extra costs as well.
Difficulty to agree on price	4	The consequence may be that the collaboration is ended.
Unpredictable heat/cold supply	4	Extra costs may be caused if back-up installations need to be used often. Even worse is if the end-users are affected. That may create discontent and costumers may eventually chose another option for heating/cooling.
Energy is not a core business	3	If energy is far from the core business of the industry, there is risk that the management is not prioritising handling of issues related to the collaboration.
The waste heat/cold is the only or main source of heat/cold	2	If the WH/C is the only source, the costumers may be highly affected by a failure in heat/cold production. This may increase the risk of costumers leaving the cooperation. However, normally there is back-up to some extent, which will decrease the consequences of this risk.

7.1 Lighthouse cluster

In the interviews with GOTE and VEAB, the experience from already made investments in industrial excess heat recovery was evaluated in terms of risk. The evaluation describes how the risks were perceived before the investments were made and the risk of terminating the cooperation.

7.1.1 GOTE (Sweden)

GOTE considers the likelihood for updated processes removing the waste heat generating process as medium due to that more efficient processes could result in lower available temperatures of the waste heat.

In GOTE's case, a wastewater treatment plant in combination with four heat pumps contributes with heat to the district heating network. GOTE are aware of the risk of that a heat pump could break down, but the likelihood of the risk is estimated as low. The consequence is also considered as low due to the redundancy of the three remaining heat pumps if one fails.

The likelihood of the industry would use of the heat/cold internal instead of selling it is assumed as low when considering the refineries. The risk could though be bigger with suppliers with smaller volumes where the industry would need the heat internally at low outdoor temperatures. GOTE has not entered into small waste heat collaborations, the refineries constitute the base load.

The risk of the refinery activity to cease is assumed as small, the trend is rather heading toward using more energy to produce fossil free fuels in the refineries, hence more excess heat. The consequence

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would however be high, e.g. to build a new CHP to replace the waste heat would take at least five years.

The likelihood of the refineries to invests in other heat/cold solutions is estimated as very low.

Regulations is seen a relevant parameter, in the case of misdirected regulations inefficient solutions could be the result. One way to promote regulations that benefits waste heat recovery is by lobbying present arguments to related authorities. The likelihood of unclear regulations is considered as medium high.

The technical know-how for district heating and waste heat is not an issue in Sweden, however, it could be more related to district cooling since it is not as common. The technical issue while developing the network or installing equipment are often rather limited, hence the consequence is estimated as medium.

By arranging explicit contracts with agreements on how to set the price of the heat, and a time frame on when to renew it, the risk of conflicts related to this matter decreases. GOTE consider it as more of a risk before the investment is made than after the contractual arrangements between the parts are finalized.

The district heating company and the refinery is dependent on each other. The refineries have high availability and predictability of the waste heat and the planed stops are well communicated. Waste heat recovery is not a core business for the refineries but is not considered as an issue since the refineries need to remove the heat in order to execute the core business. The alternative of the refineries investing in e.g. a cooling tower instead is stressed as unlikely.

The waste heat from the refineries is one of several sources connected to the district heating network in Gothenburg.

Table 16 Risk heat map GOTE

	Likelihood (1-5)	**Consequence (1-5)**	**Score**
Updated industrial processes removing the waste heat/cold generating process	2	5	10
Technical issues with heat pump	2	1	2
Internal use of the heat/cold instead of selling it	1	5	5
Small heat/cold volumes	1	3	3
The industrial activity ceases	1	5	5
The heat/cold receiver invests in other solutions	1	4	4
Unclear regulations	2	3	6
Lack of technical know-how	1	3	3

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Difficulty to agree on price	2	4	8
Unpredictable heat/cold supply	1	4	4
Energy is not a core business	1	3	3
The waste heat/cold is the only or main source of heat/cold	1	2	2

7.1.2 VEAB (Sweden)

With long-term contractual arrangements, the likelihood of removing the waste heat generation due to updated industrial processes is limited. As the pulp mill is still expanding the activity on site the likelihood of the industry activity ceases is stressed as low, but the consequence would be high if it happened.

The pulp mill is already today using some of the waste heat to generate electricity, the remaining waste heat is delivered to the district heating company. The likelihood of the industry to use the waste heat internally and no longer selling it is considered as low.

The threshold for the industry to use another alternative to cool the process is considered as high, and the likelihood for the collaboration ending due to this factor is low.

The technical know-how is good in Sweden regarding building the needed infrastructure and the requirements on the industrial facilities, the likelihood is considered as low.

Regarding the factor of difficulties to agree on the price it can change over time due to person dependency at the collaborative partners and the common organizational memory fading. It is important to set a win-win agreement between the parties. Issues can though occur even when having long-term contracts with continuous price dialogues every second year. VEAB considers the likelihood of the risk factor as medium (3).

It is important with predictable heat supply, and the pulp mill have one planned revision per year. At some occasions unplanned stops though occur which VEAB are aware of, the likelihood is considered as medium (2). The pulp mill is not the only heat supplier to the district heating network, but it contributes with the major part of the volume.

Table 17 Risk heat map VEAB

	Likelihood (1-5)	Consequence (1-5)	Score
Updated industrial processes removing the waste heat/cold generating process	1	5	5
Technical issues with heat pump	N/A	N/A	N/A
Internal use of the heat/cold instead of selling it	1	5	5
Small heat/cold volumes	1	3	3

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The industrial activity ceases	1	5	5
The heat/cold receiver invests in other solutions	1	4	4
Unclear regulations	1	3	3
Lack of technical know-how	1	3	3
Difficulty to agree on price	3	4	12
Unpredictable heat/cold supply	2	4	8
Energy is not a core business	2	3	6
The waste heat/cold is the only or main source of heat/cold	5	2	10

7.2 Demo sites

The risk heat mapping of the four demo sites assessed is presented in the coming sub-chapters.

7.2.1 ISVAG (Belgium)

Since ISVAG is a waste incineration plant with electricity generation, the waste heat is an inevitable by-product. Thus, the likelihood for removal of the waste heat due to updated industrial processes was estimated to zero. Since the heat is of high temperature no heat pump is planned to be used. Also, since there are no other internal processes with heat demand, there is no risk of internal use of the heat instead of selling it. The volume of heat is relatively large, therefore the risk of the cooperation being terminated prematurely, as found in the Swedish experience [1], is small.

Based on the result of the analysis of WtE sector (Appendix B. Analysis of risk for industrial closure) and the fact that a new WtE-plant is currently being built, the likelihood of ceased industrial activity is estimated to small. However, since the upcoming renewal of the environmental permits may lead to uncertainties, the likelihood is set to 1 on the scale 0-4.

The likelihood that the heat receiver will invest in other solutions after some time is set to 1. The likelihood is low but based on the Swedish experience there is always a risk at the time for reinvestment.

In general, heat networks are untested technology in Belgium. There is no legal framework and there is lack of technical know-how in the country. Large risks are associated with this, e.g. if a legal framework is introduced which does not favour industrial excess heat, or if the technical installations are delayed or incorrectly executed due to lack of technical know-how.

According to the interview, difficulty to agree on the price of heat is one of the essential barriers. Hence, the risk associated with this has been estimated to a high value.

In general, the heat supply is predictable which means that the risk associated to unpredictable heat generation is low.

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For ISVAG, energy is part of the core business which implies no risk for terminated cooperation due to that. However, since the heat from ISVAG will be the only source of heat, there is a high business risk related to that.

Table 18 Risk heat map ISVAG

	Likelihood (1-5)	Consequence (1-5)	Score
Updated industrial processes removing the waste heat/cold generating process	1	5	5
Technical issues with heat pump	N/A	3	N/A
Internal use of the heat/cold instead of selling it	1	5	5
Small heat/cold volumes	1	3	9
The industrial activity ceases	2	5	10
The heat/cold receiver invests in other solutions	1	4	4
Unclear regulations	4	3	12
Lack of technical know-how	4	3	12
Difficulty to agree on price	4	4	16
Unpredictable heat/cold supply	1	4	4
Energy is not a core business	1	3	3
The waste heat/cold is the only or main source of heat/cold	5	2	10

7.2.2 IMERYS (Belgium)

Since there are plans to expand the production, the likelihood for removal of the waste heat was estimated to zero; it is more likely to increase. Since the heat is of high temperature no heat pump is planned to be used. There is no risk of internal use of the heat instead of selling it. The volume of heat is relatively large, therefore the risk of the cooperation being terminated prematurely, as found in the Swedish experience [1] and as have been described in Chapter 2, is small.

Based on the result of the analysis of industrial sector (Appendix B. Analysis of risk for industrial closure) there is an increasing demand for the products and the likelihood of ceased industrial activity is estimated to small.

The likelihood that the heat receiver will invest in other solutions after some time is set to 1. However, it is difficult to predict. The likelihood is low but based on the Swedish experience there is always a risk at the time for reinvestment.

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As described for ISVAG, heat networks are untested technology in Belgium. There is no legal framework and there is lack of technical know-how in the country. Large risks are associated with this, e.g. if a legal framework is introduced which does not favour industrial excess heat, or if the technical installations are delayed or incorrectly executed due to lack of technical know-how.

According to the interview, difficulty to agree on the price of heat is one of the essential barriers. Hence, the risk associated with this has been estimated to a high value.

IMERYS has high availability and predictability of the waste heat, so the risk related to unpredictable heat availability is low.

Since IMERYS are investing largely in waste heat recovery, the risk for terminated cooperation due to that energy is part of the core business is estimated to be low. However, since the heat from IMERYS will be the only source of heat, there is a high business risk related to that. More heat sources could be added later.

Table 19 Risk heat map IMERYS

	Likelihood (1-5)	Consequence (1-5)	Score
Updated industrial processes removing the waste heat/cold generating process	1	5	5
Technical issues with heat pump	0	3	0
Internal use of the heat/cold instead of selling it	1	5	5
Small heat/cold volumes	2	3	6
The industrial activity ceases	1	5	5
The heat/cold receiver invests in other solutions	2	4	8
Unclear regulations	4	3	12
Lack of technical know-how	4	3	12
Difficulty to agree on price	4	4	16
Unpredictable heat/cold supply	1	4	4
Energy is not a core business	1	3	3
The waste heat/cold is the only or main source of heat/cold	5	2	10

7.2.3 ENCE (Spain)

Since pulp industries have vast amounts of waste heat, the likelihood of waste heat being removed due to updated industrial processes is estimated to zero. Also, heat pumps are not planned to be

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used. Furthermore, even if more of the heat is used internally, there will still be vast amounts of waste heat for export.

The volume of heat is large, about 90 GWh per year, therefore the risk of the cooperation being terminated prematurely, as found in the Swedish experience [1] and as have been described in Chapter 2, is small.

Based on the result of the analysis of industrial sector (Appendix B. Analysis of risk for industrial closure) and the fact that the company has invested largely in this particular site, the likelihood of ceased industrial activity is estimated to small.

In this case the end-users are public entities which are assumed to have a long-term commitment. Hence, the likelihood of end-users to change to another heat source has been estimated to be at a low value, 1 on the scale 0-4.

Regarding the regulatory framework related to use of industrial waste heat, Spain is promoting district heating and even though waste heat is not classified as a renewable resource, it is promoted regionally. Nevertheless, great regulatory uncertainties remain. Accordingly, since district heating and use of industrial excess heat is unusual in Spain, the technical know-how is low which implies risk of less accurate installations. Since there are a few district heating networks though, the likelihood if this risk is set to the medium value 2.

Since the heat will be given away for free, there is little likelihood of disagreement on price. However, the investment in piping and other equipment need to be paid for, and the price to the end-user needs to be agreed upon.

According to the interviews, the end-user will not need back-up boilers since the heat from ENCE will be stable and they will use two different heat boilers which make the heat generation redundant.

Even though heat recovery is not the core business of ENCE, it is highly related to the core business since the heat needs to be cooled off.

The heat from ENCE will be the only heat source, which implies a certain business risk.

Table 20 Risk heat map ENCE

	Likelihood (1-5)	**Consequence (1-5)**	**Score**
Updated industrial processes removing the waste heat/cold generating process	1	5	5
Technical issues with heat pump	0	3	0
Internal use of the heat/cold instead of selling it	1	5	5
Small heat/cold volumes	1	3	3
The industrial activity ceases	1	5	5

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The heat/cold receiver invests in other solutions	1	4	4
Unclear regulations	3	3	9
Lack of technical know-how	3	3	9
Difficulty to agree on price	2	4	8
Unpredictable heat/cold supply	1	4	4
Energy is not a core business	2	3	6
The waste heat/cold is the only or main source of heat/cold	5	2	10

7.2.4 LIPOR (Portugal)

Since LIPOR is a waste incineration plant with electricity generation, the waste heat is an inevitable by-product. Thus, the likelihood for removal of the waste heat due to updated industrial processes was estimated to zero. Since the heat is of high temperature no heat pump is planned to be used. Also, since there are no other internal processes with heat demand, there is no risk of internal use of the heat instead of selling it. The volume of heat is relatively large, therefore the risk of the cooperation being terminated prematurely, as found in the Swedish experience(2) and as have been described in Chapter 2, is small.

Based on the result of the analysis of WtE sector (Appendix B. Analysis of risk for industrial closure) and since there are relatively few WtE-plant in Portugal, the likelihood of ceased industrial activity is estimated to low.

The end-user of the heat is an airport. The likelihood that the airport chose another heat source when the installation has been done, is judged to be unlikely but not impossible.

In Portugal there are no current regulations or policies regarding industrial waste heat. Hence, the business risk due to uncertainties in the regulatory framework is estimated to be high. Also, there is lack of technical know-how regarding piping and heat recovery.

In the interview it was stressed that it is important to have a competitive pricing since gas and electricity prices are low. The likelihood of risks related to agreement on price is set to medium level, 3.

The industrial process is stable and thus the heat generation is predictable. Also, since the WtE plant has energy as part of its core business, the risk related to non-core business is set to zero.

However, since LIPOR will be the only heat source there is a relatively high business risk related to that.

Table 21 Risk heat map LIPOR

	Likelihood (1-5)	Consequence (1-5)	Score
Updated industrial processes removing	1	5	5

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the waste heat/cold generating process			
Technical issues with heat pump	0	3	0
Internal use of the heat/cold instead of selling it	1	5	5
Small heat/cold volumes	1	3	3
The industrial activity ceases	1	5	5
The heat/cold receiver invests in other solutions	2	4	8
Unclear regulations	3	3	9
Lack of technical know-how	4	3	12
Difficulty to agree on price	3	4	12
Unpredictable heat/cold supply	1	4	4
Energy is not a core business	1	3	3
The waste heat/cold is the only or main source of heat/cold	5	2	10

7.3 Summary of the risk heat scores

In the table below the total risk scores for the analysed sites and the number of scores which exceeds five are presented. ISVAG and IMERYS have the highest risk scores, which mainly depends on the lack of regulatory framework for district heating and industrial waste heat recovery in Belgium.

Table 22 Summary of risk heat scores

	GOTE	VEAB	ISVAG	IMERYS	ENCE	LIPOR
Total score	57	64	84	86	68	76
Number of scores >10 (high)	0	1	3	3	0	2

In the web diagrams below, Figure 10, a small surface implies low business risk. Also, there should preferable be no values that "stretch out" close to the edge. It is found the ENCE has been estimated to have the best risk profile, while ISVAG and IMERYS have the least favourable risk profiles. It can also be noticed that the maximum hypothetical value of 25 is not reached in any of the cases.

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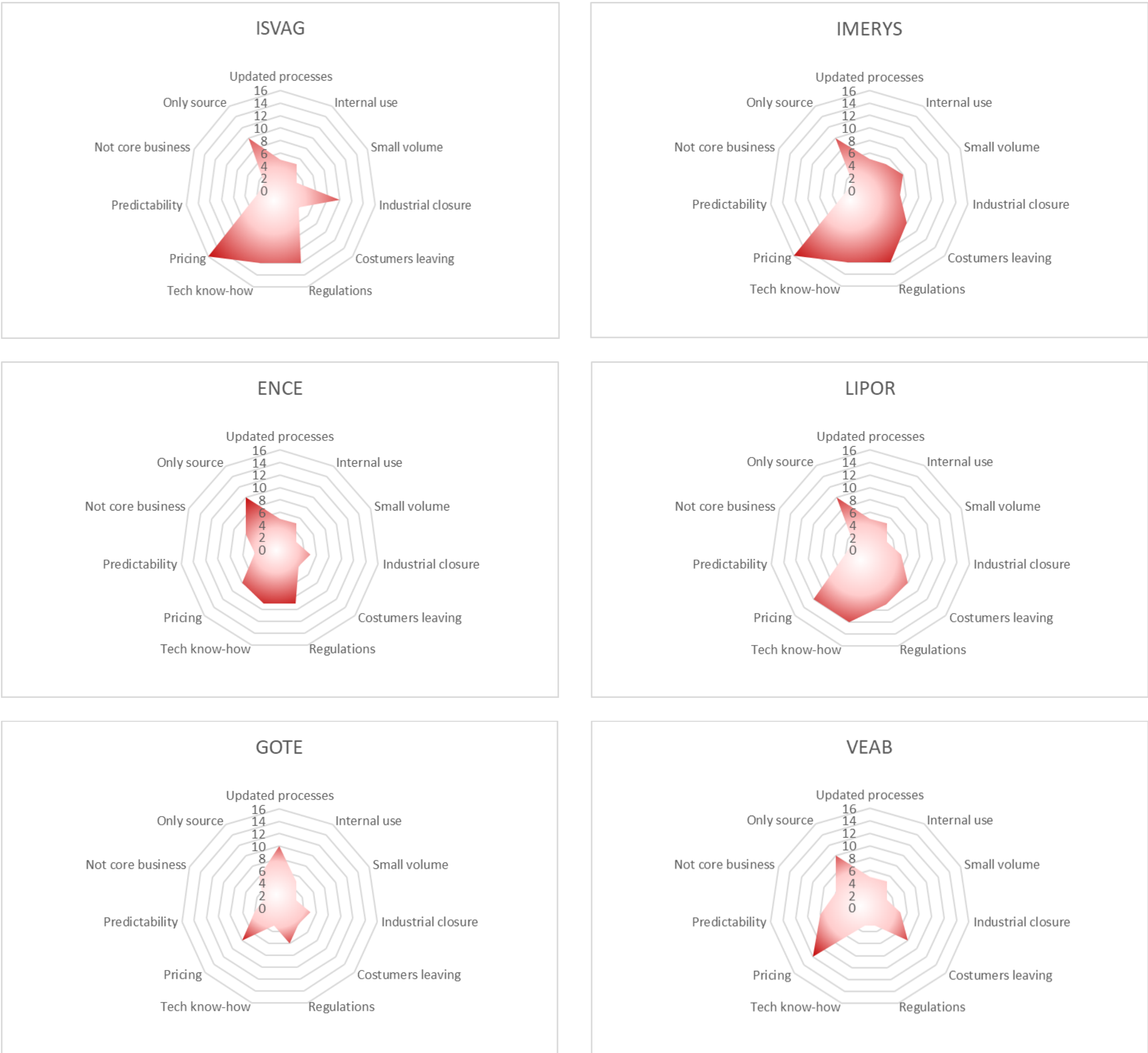

Figure 10 Web diagrams illustrating the risk heat map for four of the SO WHAT demo sites and the Swedish Lighthouse cluster.

7.4 Impact of fluctuating RES integration on business risks

Table 23 presents a qualitative analysis of the impact of fluctuating RES integration on the business risk in the heat map. Depending on the factor fluctuating RES integration can potentially reduce, increase or not have an impact on the business risk.

Table 23 Analysis of the impact of fluctuating RES integration on the business risks

	Impact of fluctuating RES integration on business risks
Updated industrial processes removing the waste heat/cold generating process	Can lead to a slightly reduced business risk, but not a major impact. For example, an investment in solar heat could sustain even if the excess heat in the industrial process would be removed.
Technical issues with heat pump	Not an impact. RES integration does not impact the risk of technical issues with heat pumps. Investments in RES

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	electricity production technologies only changes the shares of used electricity production mix.
Internal use of the heat/cold instead of selling it	Potentially a slightly reduced risk, but not a major impact. For example, an investment in solar thermal could remain even if the industrial excess heat would be removed.
Small heat/cold volumes	Not an impact.
The industrial activity ceases	Not an impact.
The heat/cold receiver invests in other solutions	Not an impact.
Unclear regulations	Investing in RES can result in more regulations to take into account. This could possibly increase the risk a bit.
Lack of technical know-how	Introducing RES could result in more new techniques to the investors and with that increased need of technical know-how.
Difficulty to agree on price	Not an impact.
Unpredictable heat/cold supply	RES heat investments could possibly stabilize the heat production to some extent, and by that reduce the risk.
Energy is not a core business	The investment in RES could be seen as an additional element not related to the core business.
The waste heat/cold is the only or main source of heat/cold	An additional heat source can reduce this risk somewhat.

8 Discussion and conclusions

The focus of this deliverable is on evaluating business risk of industrial WH/C recovery. The Swedish experience from earlier studies is that the risk of industrial cooperation shutting down is perceived as large and troublesome to investors in industrial waste heat recovery. In this deliverable new knowledge has been generated on the risk of industrial closure based on Swedish data and on the risk of industrial closure of the industrial demo sites of SO WHAT.

The risk of industrial closure, which was perceived as large in earlier studies with Swedish experience, has been identified as a risk with severe consequences but very low likelihood. This conclusion is derived on combining the industrial sector analysis and perceived risks according to the interviews with the SO WHAT demo sites.

Other risks have been identified to have the highest scores (likelihood times consequence) in the risk heat maps derived are:

- The lack of regulations or uncertainty in regulatory framework on waste heat recovery. As a result there is no standardization on how to recover the heat. For some countries permit processes are not established for waste heat recovery processes.
- The lack of technical know-how is getting high risk scores in the countries that historically lack district heating and cooling. There is a risk that the competencies needed are not present or that constructions are made in an inefficient manner.

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- For many demo sites the process to agree on pricing is considered as high risk: this is often a result from the two parties not knowing how the processes of the other party work (e.g. waste heat in Summer is, for a district heating provider not very valuable)
- One main heat source is also getting high risk scores; simply because a strong dependency is created where the stakeholders are reliant on a resource outside of its own control. From being independent, a dependence on an external part is introduced.
- In Sweden, the use of a heat pump for exploitation of industrial excess heat was shown to increase the risk of premature closure of the cooperation. None of the SO WHAT cases are planning to use a heat pump. However, the use of absorption chillers could be analogue in the sense that it adds complexity to the system and adds electricity demand.
- The importance of some risks is reduced over time. The risk of industrial closure is, for example, perceived to be lower once the relationship is established and up and running. Also, a large volume of heat recovery is seen as a riskier investment before it is undertaken whereas after it has been undertaken the large volumes instead have a stabilizing effect. Post investment, other risks become more pronounced, like perceived differences of the value of the waste heat (e.g. the price).

The identified high-risk factors above can to some extent be mitigated if measures are taken. Examples of mitigation measures are:

- Issues regarding building DHN and piping could be simplified through involving a third party (ESCO). Such a party can, for example contribute with needed expertise. For instance, building district heating networks could be an opportunity for a contractor that is currently building gas grids. This is the case in Belgium where the contractors are both building natural gas piping and DHN [4], but unfortunately there are only a few contractors available resulting in the prices of constructing the infrastructure can vary a lot depending om when and where the project is planned.
- The most important mitigation activity is to have clear contract outlining responsibility and what happens in the case of failure to deliver waste heat at given volumes and temperatures. To ensure efficient contracting the knowledge transfer from experienced partners to beginners in the field is very valuable and can save much time and effort in the process of establishing the heat recovery.
- Companies and other actors can to some extent influence issues related to regulations, in the case of misdirected regulations leading to inefficient solutions. One way to promote regulations that benefits waste heat recovery is to continuously keep up to date in the area and by lobbying present arguments to related authorities. Particularly, the local or regional authorities might have willingness to encourage DHN and exploitation of waste heat sources.

The analysis conclude that some risk aspects may be reduced with fluctuating RES integration, while other may increase or not have be affected at all. For example, an investment in solar thermal could stabilize the heat production to some extent and remain even if the industrial excess heat would be removed, resulting in a potentially reduced business risk. Business risk that may be increased are related to unclear regulations, technical know-how and if energy is not the core business for the company, this due to that the investment in fluctuating RES would add one more new technology to handle.

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For investors, a risk premium, e.g. in terms of increased interest rate, is the return an investor needs to invest in anything else than a risk-free asset (often a government bond). In the context of waste heat recovery investments there are known factors that add risk to the investment:

- The factors can be external to the investment (like competitive alternatives or policy frameworks that do not incentivize heat recovery)
- Technical (lower temperatures than expected in the waste heat or smaller volumes than foreseen)
- Contractual (the difficulty to identify a value of the waste heat that both district heating company and waste heat provider agree on) or
- The risk that the industry closes resulting in the heat source being terminated.

In this study of waste heat recovery investments and risk the demo sites in the SO WHAT project have been analysed and the conclusion is the same: the risk of industrial closure is not the largest one, but it can have detrimental consequences if it materialises. It is also possible to conclude that other risks need to be addressed by an investor to identify a justified risk premium for waste heat recovery investments.

Finally, recovery of industrial excess heat for use in district heating systems can be characterised by great political interest, high potential due to low utilisation and often high profitability. The analysis showed that some risk events, which are perceived to be large (like closure of industrial site), are less risky than what is often claimed. What appears to be a main challenge is the shifting boundary conditions between stakeholders: engaging in a relationship making the heat supply reliant on a heat source that is outside of the control of the heat provider.

To summarise, we find that the different risks vary between European countries, industrial sectors and with choice of technology. However, the major part of the risks can be mitigated with well-designed contracts and well-thought-through partner arrangements: facilitating for the parties involved to learn about each other's processes.

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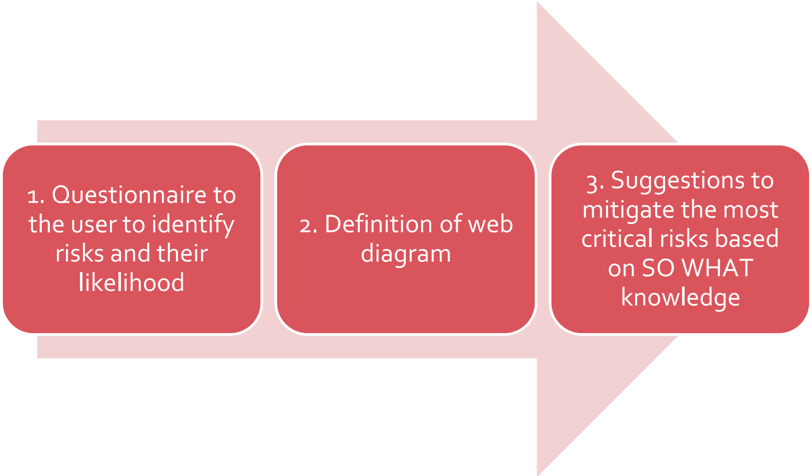
9 Input to the SOWHAT tool

In order to be able to mitigate the risks or add a risk premium to the investment, the first step is to audit the risks. In the SO WHAT tool, this may be performed through risk heat mapping like the method used in this report, for example using likert scale.

Input regarding likelihood of risk aspects will be given by the tool user. For example, the user could estimate the likelihood in a list of questions that may be answered on a scale 1 to 5. The consequences of the risks may be estimated in accordance to the estimations in this report, scale 1 to 5.

The risk heat score is then calculated as likelihood times consequence, for each risk, and presented in a web diagram.

The risk web diagram should be followed by suggestions of risk mitigation actions.



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Appendix A. Questionnaire

Background

1. Does WH/C cooperation already exist in the demo site region? (Between which partners, what is included etc?) If yes, what was the experience and what was concluded?

2. Has WH/C cooperation been discussed between partners within the demo site or with other stakeholders in the region earlier? (Which stakeholders? When? Any results so far?)

3. Which partners are considered for WH/C cooperation within the SO WHAT project?

4. What do the demo site partners expect from the SO WHAT project? (Why have they joined the project? Do they wish to sell or buy heat or cold?)

5. What incentives do different partners in the cluster have? (Extra revenue for selling heat or cold, policy demands on industries, avoid building new heat or cold production unit, etc)

Risks with WH/C collaboration

Risk 1.1 Risk of WH/C collaboration ending due to termination of industrial activity

6. To what extent do you consider that there is a risk that the industry that delivers the excess thermal energy shuts down?

7. To what extent do you consider that the collaboration will impact the competitiveness of the industry that delivers the excess thermal energy?

Risk 1.2 Risk of collaboration ending due to reduced WH/C availability

8. To what extent do you consider that there is a risk of collaboration ending due to reduced WH/C availability? (E.g. due to industries performing more internal energy integration, or introducing a new process that could use excess heat internally)

Risk 2 Risk of collaboration ending due to WH/C user choosing other heat supply.

9. Will a heat pump be needed to enable WH/C recovery?

10. Do you consider it a risk for the collaboration if a heat pump is used?

11. How predictable is the availability of industrial WH/C? How important is predictability?

12. Have you considered how to keep back-up heat supply in case WH/C cannot be delivered? (At the WH/C deliverer or user?)

13. How dependent will the WH/C user be on a single WH/C deliverer?

14. What heat or cold sources is being promoted in policy and regulation?

Risk 3 Volume of heat delivery

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15. To what extent do you consider that the volume of the heat or cold delivery impose a risk?

Risk 4 Risk of RES integration at the industrial site or in the district heating/cooling (DHC) network

16. Do you have, or plan to have, any RES with fluctuating availability in the current DH/C or at the industrial site (solar thermal/electrical, integrated wind power)?

    If yes;

    17. What motivates the decision to integrate RES in the DH/C network or at the industrial site?
    18. Do you experience any risks with having intermittent RES in the DH/C network or at the industrial site? What are the risks?
    19. Do you think that a combination of excess thermal energy and RES lowers the security of supply compared to having only WH/C or only RES?

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Appendix B. Analysis of risk for industrial closure

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1 Introduction

One of the objectives of Task 3.3 "Business and risk models for industrial waste heat/cold recovery and RES integration" is to generate new knowledge on the risks of industrial closure of the industrial sites of the SO WHAT project. As the risk of industrial closure is affected by the development of the different markets on which the industries are present, the industry analysis presented in this report aims to give an understanding of the international and national markets associated with the demonstration sites of the SO WHAT project. In addition, the competitiveness of the companies is briefly assessed.

The analysis is mainly based on reports from international and national business associations and international organizations such as the European Commission (EC), the International Energy Agency (IEA) and the Organization for Economic Co-operation and Development (OECD), market reports from consultancy companies and the annual reports from the industries, and some peer-reviewed articles.

2 Summary of analysis

The industry analysis provided in this annex aims to give a better understanding of the international and national markets associated with the demonstration sites of the SO WHAT project and to briefly assess the competitiveness of the companies. A summary of the analysis is presented in Table 1. The table describes the different demo sites in terms of which specific industry and NACE category it belongs to and in which country it is situated. The demo sites have also been given a risk value from low to high based on the risks associated with the specific markets and the competitiveness of the demo sites. Please note that the MPI demo site had not been chosen at the time of the analysis.

Table 1 Summary of industry risk analysis

Company	Demo site	Industry	NACE category	Country	Risk
TBD	MPI	Steel	Metal products	UK	High
Lipor	Lipor Maia	Waste-to-Energy	Waste management	POR	Low
ISVAG	ISVAG	Waste-to-Energy	Waste management	BEL	Low
Martini&Rossi	Pessione destillery	Food & Beverages	Beverages	ITA	Low
Rompetrol Rafinare	Petromidia refinery	Refined petroleum	Coke and refined petroleum	ROM	Medium
Preem	Göteborg Energi	Refined petroleum	Coke and refined petroleum	SWE	Medium
St1	Göteborg Energi	Refined petroleum	Coke and refined petroleum	SWE	Medium
Ence	Ence Navia	Pulp & Paper	Pulp & Paper	ESP	Low
Södra Cell	Varberg Energi	Pulp & Paper	Pulp & Paper	SWE	Low
Umicore	Umicore	Cobalt and germanium	Metal products	BEL	Low
Imerys	Imerys	Carbon black	Chemicals	BEL	Low

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3 Steel

China is dominating the global crude steel market in terms of global production, but the global market is more diversified as Chinese steel is mainly used domestically. The EU steel sector is experiencing a negative trend because of weakened exports and investments. The UK steel industry is also in decline, induces by the lower margins created by low prices on steel products, and UK demand for steel products are lower than before the 2008-2009 financial crisis. Today the UK is a net importer of steel products, mainly importing from other European countries.

3.1 The steel market

The steel industry is considered a global market with international competition, a large share of the steel is traded over national borders [1], see Figure 1. China is the largest producer of crude steel. In 2018 the Chinese production of crude steel was 51% of the world's total production. This share has increased significantly since 2000. China is also the largest exporter of semi-finished and finished steel products, as could be seen in Figure 2. However, the Chinese exports share was only 15% of the total steel products traded worldwide in 2018.

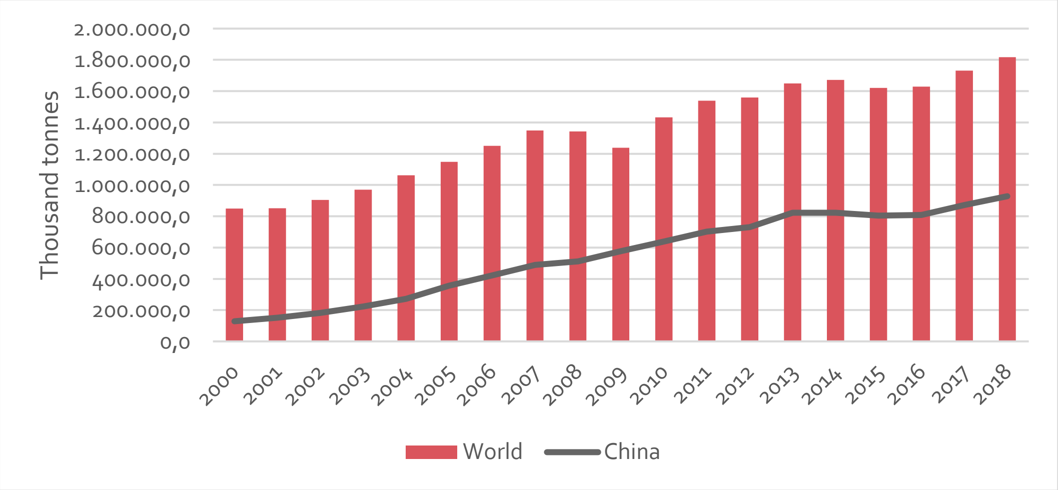

Figure 1 Total, production of crude steel, 2000-2018

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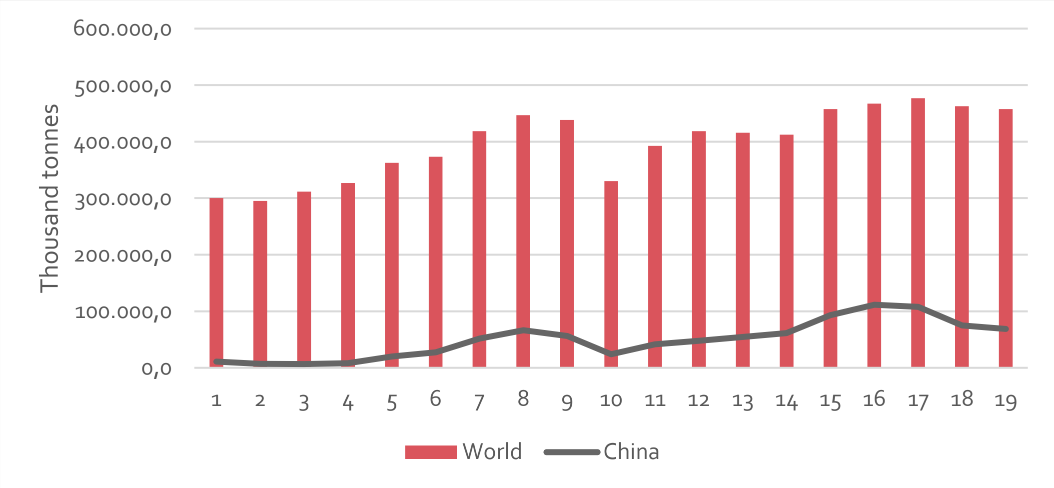

Figure 2 Total exports of semi-finished and finished steel products, 2000-2018

The production of crude steel may be affected by an increased recycling of steel scrap. According to different forecasts for the global steel demand, the steel production will be 50% higher in 2050 compared to today's level and it is estimated that a large share of this increase could be covered with scrap steel [2].

In the short term, the European steel market has experienced volatility the last couple of years. EUROFER, the European Steel Association, has identified an ongoing negative trend due to a downturn in EU's manufacturing sector as a result of weakened exports and investments. Market risks are associated with import distortions and a global overcapacity of steel products that may undermine the stability of the EU steel market [3].

The UK has seen a decline in the steel industry in the past 25 years, not in line with the general positive trend for manufacturing industries [4]. Between 1990 and 2016 the economic output from the steel industry has declined with around 50% in the UK. The importance of the steel industry for the economy has also declined during this period, just as the level of employment in the sector. The global overcapacity of steel products has been pushing down the prices and as UK overhead costs are relatively higher than in some other countries it is creating higher comparative expenses of steel produced in the UK [4]. The economic viability of the UK steel industry has even been questioned by some analysts and international investors. During the Autumn of 2015 the UK saw a steel industry crisis and major plants in Redcar, Scunthrope, Scotland and South Wales regions had to close down or reduce their production capacities [4]. As a result, the steel economic output fell down with 30 % in 2016 compared with 2015. In response to this the Government introduced measures to support the industry. Since the low steel prices in 2015-2016 the prices have increased slightly [5]. The UK demand for steel mill products is, however, still lower than before the financial crisis in 2008-2009 and imports exceed the domestically produced steel products since 2000; other European countries are the main suppliers.

At the point of this market assessment the steel industry to be part of the project had not yet been selected, as a result the industry specific market assessment has not been performed for the steel industry demo site.

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4 Waste-to-Energy

Solid waste management is a mainly a local responsibility that is either operated by local public entities directly, or through mixed public-private entities. In the EU waste disposal segment (e.g. landfills and waste incinerators) operate in a somewhat competitive market but are still restricted by their assigned territorial area. Around one third of the municipal solid waste is treated by waste-to-energy, and the share has increased with EU targets for decreasing the share sent to landfills. Portugal needs to increase its share sent to landfills, meaning that the prospects for waste incinerators are good. Belgium, on the other hand is among the top performers and there are limited opportunities for new waste incinerators. The already existing plants will be of no shortage in waste supply in a foreseeable future.

4.1 The waste-to-energy market

In most countries globally the solid waste management is a local responsibility and about 70% of the waste services are overseen directly by local public entities, either directly operated by local entities or through mixed public-private entities [6]. This may suggest that regulations and policies pushing for energy recovery from waste as well as the availability of waste as a fuel, plays a greater role in shaping the future prospects for waste-to-energy facilities.

Within the European Union, local entities at the municipality level are legally obliged to provide collection systems for municipal solid waste (MSW) [7]. As a result, a number of integrated networks of municipal waste treatment facilities have been established. EU directives pushes for a management of MSW close to the location where it is generated and each member states are responsible to ensure that the MSW should be treated and disposed. The waste disposal segment, e.g. landfills or waste incineration, operates in a somewhat competitive market but are still restricted by the self-sufficiency principle that pushes the self-sufficiency in recovery and disposal in each community.

The Confederation of European Waste-to-Energy Plants (CEWEP) publishes an industry barometer each year, based on a survey sent out to European Waste-to-Energy (WtE) operators [8]. For 2019 the business climate index for the WtE industry reached an all-time high since the start of the measurements in 2012. A large number of the respondents (80 %) referred to their high utilization of capacity when rating their economic situation as good. The plants operators do also have a positive outlook on the future; 65 % believe the waste amounts going into thermal treatment will hardly decrease despite improved recycling rates, this because of the large amount of sorting residues. Mainly as a result of the EU target on decreasing landfilling of municipal waste, CEWEP has also experienced a steadily increasing demand for thermal treatment of waste.

According to the World Bank Group [6] the waste generation in Europe is expected to increase gradually over the coming years, both in terms of total waste generation and the waste generation by capita. The projections are based on that waste generation is primarily a result of Gross Domestic Product (GDP) and population growth. Europe is, however, also one of the regions with the highest waste collection rates.

Eurostat data in Figure 3 [9] show that recycling and waste-to-energy are growing in parallel and countries performing well with recycling are more likely to also have large shares of waste sent to

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waste-to-energy. In 2018, 29% of the municipal waste in EU-28 was used treated by waste-to-energy, 48 % was recycled and 23 % sent to landfills. However, half of the EU member states still send more than 40% of the MSW to landfills.

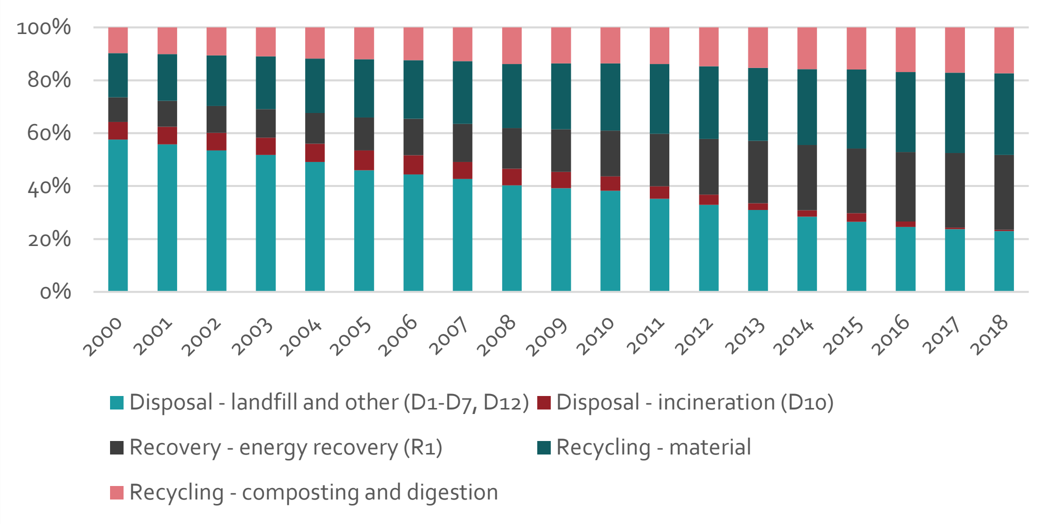

Figure 3 Treated municipal waste by waste management operations, EU28

4.2 Lipor: Portuguese waste management

The management entities of municipal solid waste (MSW) in Portugal are called SGRSU. Their responsibilities include the waste treatment, recovery and disposal. The SGRSUs were created by public financing and by joining several municipalities [10]. Lipor, Intermunicipal Waste Management of Greater Porto, is one of the SGRUSs and is responsible for the management, recovery and treatment of the municipal waste in eight associated municipalities, among them the Maia municipality [11]. Lipor was founded in 1982 and today it covers an area with approximately one million inhabitants and treats 500,000 tons of waste every year. The energy recovery plant in Maia was taken into operation in 2000 and has continuous operation year-round [12]. In 2019, 74 % of the municipal waste sent to Lipor was used for energy recovery generating approximately 170,000 MWh electricity. Nearly 90 % of the electricity produced is sent to the grid, while the rest is being consumed internally.

The Portuguese share of energy recovery in treated municipal waste has remained stable around 20 % since 2000 and the amount of waste treated by energy recovery has remained around 1000 thousand tonnes per year since the same year [9], see Figure 4. The share of waste treated sent to landfills is around 50% and needs to be decreased considerably to be able to attain the EU Directive for below 10%. This could open up for an increased demand for energy recovery from municipal waste. The World Bank has projected that the total municipal solid waste in Portugal will increase by 2% from 2016 to 2030, and 3% to 2050 [6].

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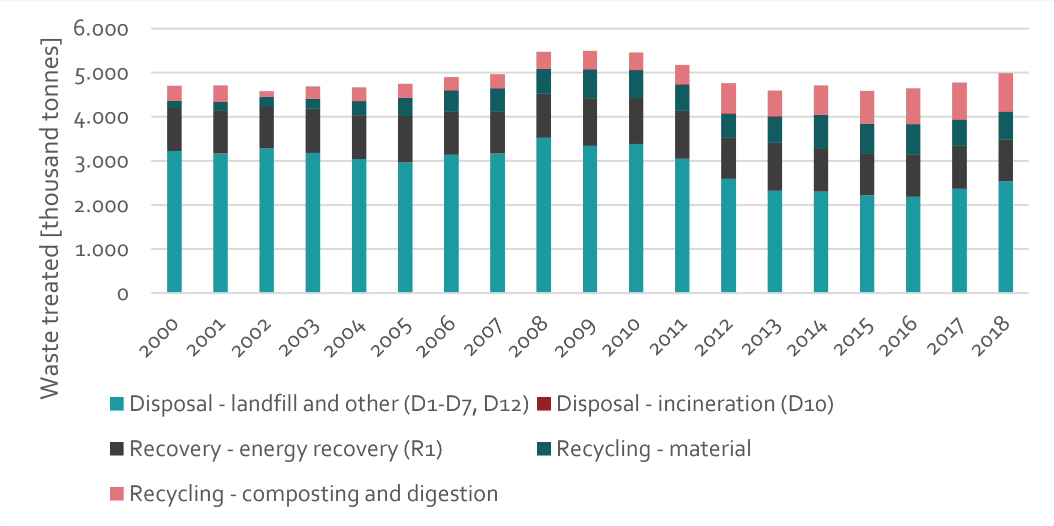

Figure 4 Treated municipal waste by waste management operations, Portugal

4.3 ISVAG: Belgian waste management

The Belgian demonstrator ISVAG is an inter-municipal partnership company for waste management founded in 1975 [13]. The ISVAG plant is located in the Flanders region. In Belgium the waste management falls under the responsibility of the Brussels Capital, Flanders and Wallonia regions. In Flanders, the waste management plan for 2016-2022 has set targets to reduce the amount of residual waste and there are also ongoing pilots on separate collection of plastics [14].

Belgium is among the top performers in EU on waste management and has already met EU recycling targets for 2020, but the report from EU commission suggest that waste incineration needs to be reduced to reach recycling targets post-2020 [14]. The Belgian share of energy recovery in treated municipal waste has seen an increase since 2000, in 2018 it was 42% [9], see Figure 5. At the same time the waste sent to landfills have decreased and is now a diminishing share of the waste treated. One could argue that as the EU goal for a maximum 10% share sent to landfills, and the stable volume of municipal waste treated in Belgium, the prospects for new waste-to-energy plants in Belgium is limited but that the existing ones will have their share of waste. The World Bank has also projected that the total municipal solid waste in Belgium will increase by 12% from 2016 to 2030, and 30% to 2050 [6].

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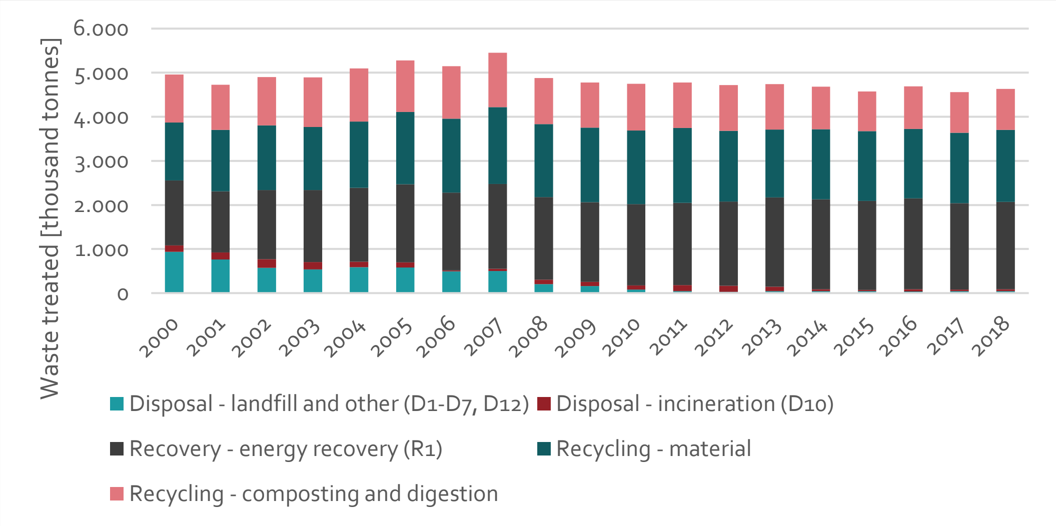

Figure 5 Treated municipal waste by waste management operations, Belgium

5 Food and Beverages

The demand for agri-food products is expected to grow substantially the coming years. Changes in the demand and the industry structure is shaping the development, and there is also an increase of global value chains. EU imports and exports have increased the past decade. EU is a world leading exporter of processed agricultural products, and beverages and bakery products contribute to a large share of the positive trade balance, but the region is experiencing competition mainly from Brazil and China. EU competitive advantages is the focus on high quality products and high food safety requirements.

Italy is one of the main exporters and importers of both sparkling wine and vermouth globally. EU is the main market but with an increased health concern and changing consumption patterns, the per capita consumption of alcoholic beverages is decreasing, and the trend is expected to continue until 2030. Export is however increasing, driven by a strong demand for EU wine with specific geographical origin (geographical indication, GI) and also for sparkling wines. Martini & Rossi is one of the top-selling vermouth brands worldwide and the company is also producing sparkling wines at the facility in Pessione.

5.1 The Food and Beverages market

The global food and beverage industry is closely linked to the agribusiness as the products are based on agricultural products. Food and agribusiness represent 10% of the global consumer spending and 40% of the global employment, hence having a large economic and social impact [15]. Despite productivity improvements the last five decades, feeding the global population is still a critical issue as the demand is expected to grow substantially the coming years. Population growth, urbanization and increased income in emerging economies, such as China, is fueling an increase in demand for food and a shift to a "rich-country" diet based more on calories, protein and processed food.

There is also an ongoing shift in the mature markets with greater emphasis on healthier diets and environmental sustainability [15]. In [16], Chomitz et al. identified four trends that will influence the

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agriculture sector the coming years: (i) we will eat differently; (ii) we will source from different places; (iii) we will produce and trade food differently; (iv) we will conduct trade with different rules (e.g. subsidies and tariffs). The four most traded crops (corn, soybeans, sugar and wheat) are the most vulnerable to these trends.

As a result of the perceived opportunities on the agri-food market, the global investments in the food and agribusiness sector is increasing massively [15]. There is also a transformation of the industry structure; Goedde et al. [15] is expecting the industry to move towards both a consolidation of firms as well as the development of smaller, specialized companies. In addition, the food and agriculture industry is increasingly organized within global value chains; different phases in the transformation of raw material into end-consumer product are located in different countries [17]. The value chains are also increasingly centralized around hubs, such as China, USA and Germany. Despite the large international trade of food and agricultural products, most products are not crossing multiple borders and in many developing countries, most of the food production and consumption remains local.

Processed agricultural products, PAP, such as alcoholic beverages and bakery products, are important for EU export [18]. The European food industry is the world's leading exporter of PAPs and has a positive trade balance. Despite an increase, the global market share of the EU has decreased in the competition from Brazil and China. Both the exports and imports of foodstuffs have increased during the last decade [19], see Figure 6. The main product category contributing to the positive balance in food stuffs are "Beverages, spirits and vinegars" (33% of the trade balance) while "Preparations of cereals, flour, starch or milk; pastrycooks' products" is second (17% of the trade balance).

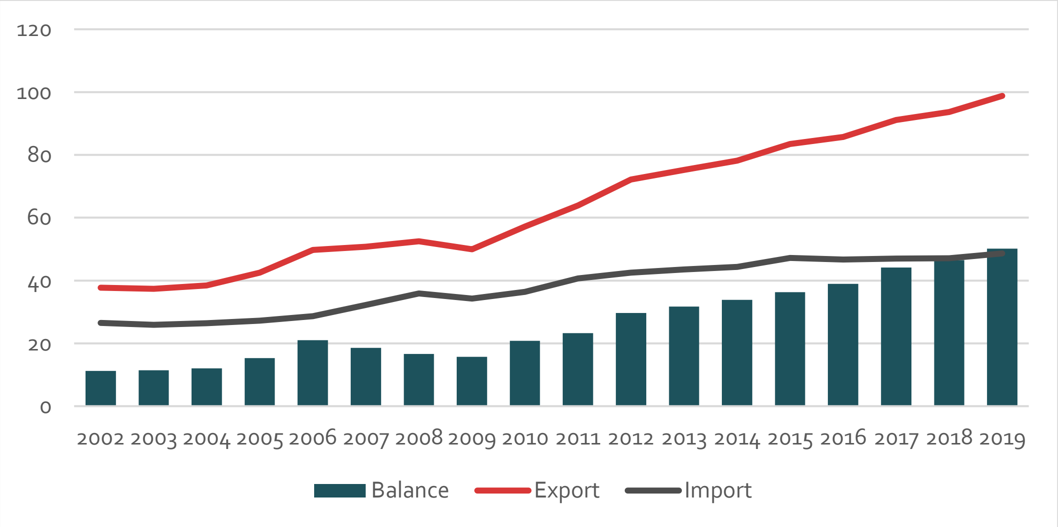

Figure 6 EU-27 trade of foodstuffs, 2002-2019 [EUR billion]. Source: Eurostat (Comext data code: DS-016894)

Most important export markets for EU foodstuffs manufacturers 2019 were the UK, USA, China, Switzerland, Russia, and Japan [19], see Figure 7.

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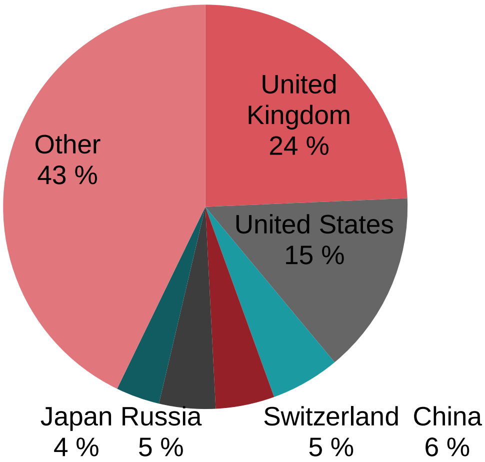

Figure 7 EU-27 Exports of foodstuffs by main partner, 2019. Source: Eurostat (Comext data code: DS-016894)

The EU foodstuffs imports were mainly from the UK, Brazil, the USA, Ivory Coast, Argentina and Switzerland [19], see Figure 8.

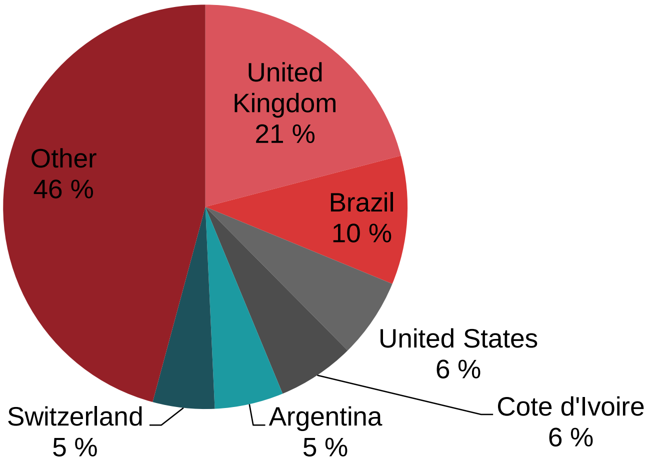

Figure 8 EU-27 imports of foodstuffs by main partner, 2019. Source: Eurostat (Comext data code: DS-016894)

In 2016, the ECSIP Consortium, on behalf of the European Commission, assessed the competitiveness of the European food and drink industry with respect to four benchmarking countries that are the European industry's main trading partners: USA, Australia, Brazil and Canada [20]. The study found that the EU food and drink industry achieved a more competitive advantage compared the trading partners on the development of the international trade-related indicators (relative trade advantage and world market share) but the performance on the economic indicators was weaker (total manufacturing, labor productivity, value added). The comparative advantages for EU manufacturers identified were the focus on high quality products and high food safety requirements, also recognized by other regions.

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5.2 Martini & Rossi: Italian manufacturer of vermouth and sparkling wines

Martini & Rossi is an Italian multi-national company with one of the headquarters located in the village of Pessione of Chieri, Italy [21]. It is part of the Martini-Bacardi group since 1992, ranked among the top five beverage groups in the world. The company has produced vermouth for nearly 150 years and has been one of the top-selling vermouth brands for more than a century. In addition to the vermouth, the company is also producing sparkling wine.

Italy is a net exporter of food, drinks and tobacco [22]. In 2010-2011 bottled wine showed by far the largest share, 16.4%, of the agri-food exports from Italy [23]. Sparkling wine was 2.5% and vermouth 0.8% of the total agri-food exports. For these three types of alcoholic beverages Italy also showed high levels of revealed competitive advantage. After France and followed by Spain, Italy is the second largest exporter of sparkling wines worldwide [24]. For vermouths and similar alcoholic beverages from grapes, Italy ranks first in exports followed by Spain and France [25]. The same three countries are also the main importers of the alcoholic beverage; Europe is the largest market for vermouth. According to [26] the global vermouth market was expected to increase around 3% annually from 2017 to 2021. Consumption is growing in America, especially USA but also in Brazil, Mexico, Argentina and Chile. The Asia-Pacific region is experiencing the fastest increase, thanks to high consumption in China, Australia, Japan and New Zealand.

80% of the wine produced in the EU is consumed within the region and five member states (France, Italy, Spain, Germany and the UK) contribute to over 70% of the wine consumed [27]. With an increased health concern and changing consumption patterns, the per capita consumption is decreasing, and the trend is expected to continue until 2030. There are however differences between types of wines. While the consumption of red wines is decreasing, the sparkling wine consumption is increasing. In total there is, however, a decline in the consumption of wines and the use of wine for distilled products (such as vermouth) until 2030. There is also an expected decline in the EU wine production, mainly due to the closure of smaller vineyards with retiring owners and/or difficulties to be competitive on the market. While the EU consumption is decreasing the exports have increased and are expected to do so slightly also until 2030, despite strong competition from outside the EU and trade tensions. The export demand is driven by a strong demand for EU wine with specific geographical origin (geographical indication, GI) and also for sparkling wines.

6 Refined Petroleum

Given current stated policies the oil demand is expected to increase globally, but stricter environmental policies could affect the development. The composition of the demand is also expected to shift from the transportation sector to petrochemicals in the coming 10-20 years. The refineries that can manage this shift and at the same time keep low operating costs will have a bright future.

EU refineries are facing increased international competition and a volatile market. In the past years EU refineries have invested in increased complexity to be able to produce more of lighter petroleum products from heavier crudes. At the same time, they are facing a declining market in Europe as a result of a decreasing demand for gasoline and fuel products. In addition, refiners rely heavily on low operating costs to attain profitability and the EU refineries have relatively high operating costs in comparison with their competitors.

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The Romanian and Swedish refineries are all focused on refined products for the transportation sector, mainly for European countries in the vicinity of the respective country, both have diversified their portfolios somewhat lately. The strategies of the Swedish refineries are driven by more stringent environmental policies on the domestic market which pushes for investments in biofuel capacity. The Romanian refinery has increased the complexity and efficiency of the plant and has also integrated the refinery with a petrochemical division. The refinery is also a strategic asset for the Romanian state, indicating that the company could expect governmental support for future survival.

6.1 The Refined Petroleum market

Since the 1990s the global demand for refined petroleum products has increased and the transportation sector is still largest in demand [28], see Figure 9.

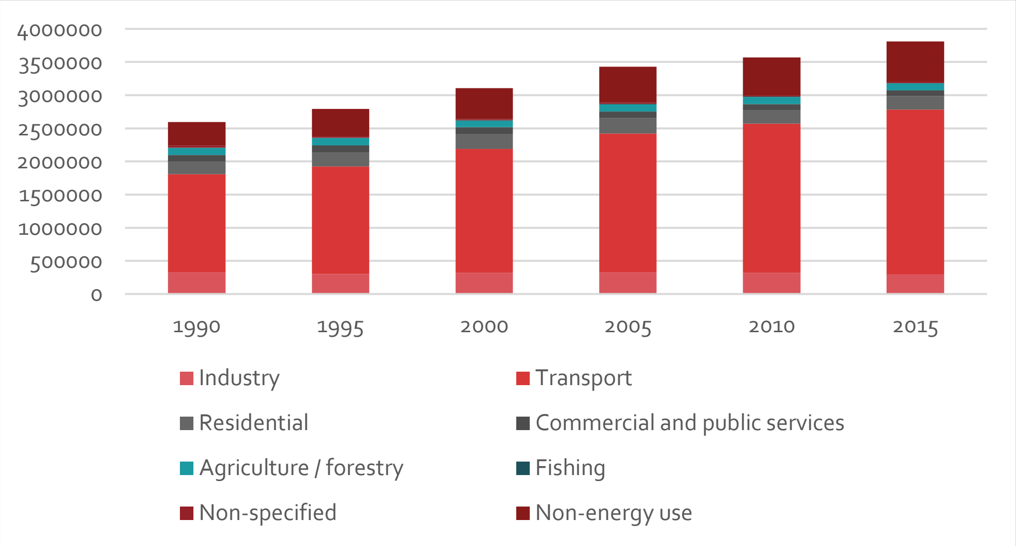

Figure 9 Oil products final consumption by sector, World

With the current stated policies, IEA is projecting that the oil demand will increase even more to 2030 and 2040 [29]. Asia Pacific and North America are the two main regions in terms of crude oil demand and will remain the largest markets for crude oil also in the long run, regardless of the total global demand decreases as a result of stricter environmental policies. IEA also sees an ongoing transformation of the global oil market. United States is becoming more dominant in the expansion of oil supplies with the increase in shale oil and the demand is changing from developed economies and transportation fuels to non-OECD countries, mainly China and India, and petrochemicals.

Currently, the main sector in terms of oil demand is the transportation sector, making the petroleum products industry vulnerable to changes in the demand for mobility; as have been illustrated with the mobility demand decrease during the covid-19 crisis [30]. As the transportation sector is dominating the oil demand, competition from renewable fuels is also important to monitor. However, the share of renewables in transport fuel demand was only 3.7% in 2018, with 93% being biofuels and the rest

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renewable electricity [31]. By 2024 the RES share is expected to rise modestly to 4.6% [31] and in 2040 it is projected to be around 8% - given the current stated policies [32].

The global refinery throughput has increased since the 1980s [33]. However the number of refineries have decreased, indicating a consolidation of the market [34]. The USA is the world's largest refiner, followed by China, Russia, India and Japan [35]. The trade in crude oil and oil products has increased since the 1970s. The three main exporting regions of refined petroleum products in 2019 were USA, Russia and Europe while the three main importing regions in 2019 were Asia Pacific (excluding China, India, Japan and Singapore), Europe and Singapore [33].

The "*crack spread*" is the difference between the cost of crude oil (e.g. Brent FOB) and the sales prices for the refined product (e.g. diesel or gasoline) and the area in which the refineries operate [36]. The refineries have little or no influence over the price of the input or output and the spread is tight, meaning that the margins are low, and the refiners rely heavily on keeping the operating costs low to be able to achieve profitability [34, 36]. The refining margins for three regional products during 2000 to 2019; (i) US Gulf Coast (USGC); (ii) North West Europe (NWE); (iii) Singapore; can be seen in Figure 10 [33]. The spreads for the three products have been volatile during these years. Short term volatility of the prices of either the crude oil or refined product can squeeze the crack spread, putting the refinery at considerable economic risk [34].

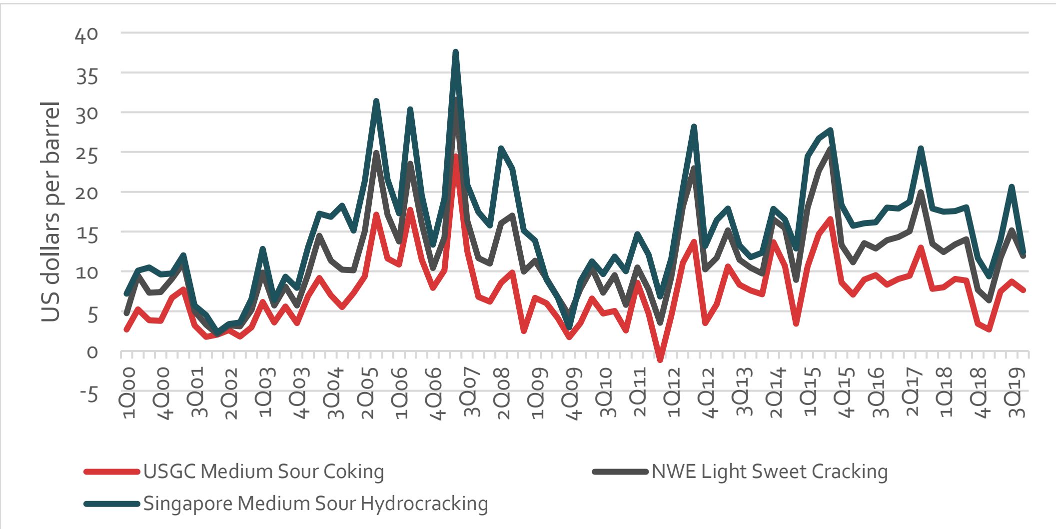

Figure 10 Refining margins 2000-2019, USD per barrel

Profitability determinants that the refineries may control are related to: (i) logistics (access to infrastructure and relevant markets; costs of inputs such as labor and energy; crude oil blend); (ii) configuration and complexity (economies of scale; energy efficiency; product slate and the achievable quality), and (iii) operational efficiency (cost management; staffing levels and labor productivity; timing of maintenance) [37].

An increased complexity, commonly measured with the Nelson Complexity Index (NCI), enables the refinery to more quickly adapt to market changes [34] by diversifying the product slate, increase the flexibility in processed crudes as well as product specifications and with respect to market conditions

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[37]. Larger complexity is however increasing the operating costs (due to higher energy costs) and the capital costs, and complexity is not necessarily correlating with the capacity to process any crude or produce any specific product. Most of the new refinery capacity that has been built since the beginning of the 2000s has been having more complex configurations [34]. This efforts have focused on increasing the output of gasoline and middle distillates (such as diesel) [38]. As these products, targeting the transportation sector, are expected to decline in demand, while the demand for petrochemical products will increase, the challenge for refineries is to adapt the production to the new demand. Several Asian refineries have integrated refineries with production of petrochemicals in different ways, and in the Middle East ways to bypass refining and produce chemicals directly from crude oil are explored.

The main sectors in EU oil products consumption are transport and non-energy use (such as the petrochemical industry) [28]. The consumption of oil and petroleum products has decreased slightly in the EU since the 1990s [39], as could be seen in Figure 11. In [37] the decline in petroleum products is explained with the lower demand for gasoline and fuel oil.

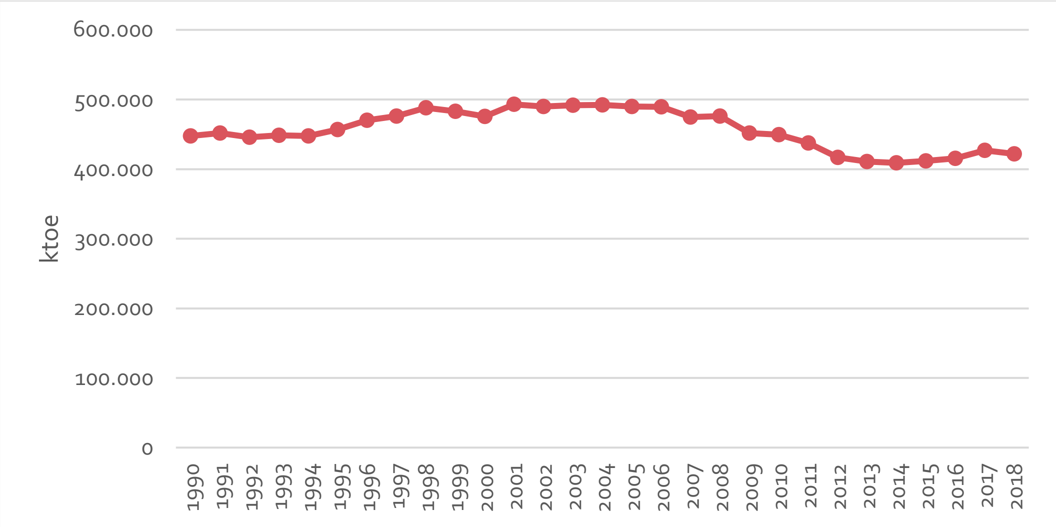

Figure 11 Oil and petroleum products available for final consumption 1990-2018, EU27

The overall production of the refined products has declined in the EU and the refineries are not running on full capacity, but there is still a mismatch in supply and demand indicating that there will be a continuing process rationalization in capacity [37] In an assessment of the economic performance of EU refineries made in 2015 [37], EU refineries faced relatively high operating costs (mainly due to relatively high energy costs) and net cash margins in the recent years had been lower than for refiners in several competing regions.

The average complexity of the European oil refineries has grown since the 2000, especially in the areas that have higher shares of the heavy crude oils (such as the Baltics and Southeast Europe) [37]. In 2012 the average NCI was 9.0 in the EU. Until the global financial crisis in 2008-2009 there were a steady grow of all types of investments in the European refineries, reflecting the upgrade in complexity. After the financial crisis the focus was more on regulatory and environmental investments.

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Nivard and Kreijkes are in [40] expecting that EU refineries will be exposed to a declining market and international competition in the medium term. Refineries that are integrated with the petrochemical industry or a sheltered inland market (e.g. not coastal refineries) may have a competitive advantage when the value chains are more integrated.

6.2 Rompetrol Rafinare: Romanian oil refinery in Novodari

The Romanian consumption of oil and petroleum products has fluctuated since the 1990s [39], as could be seen in Figure 12.

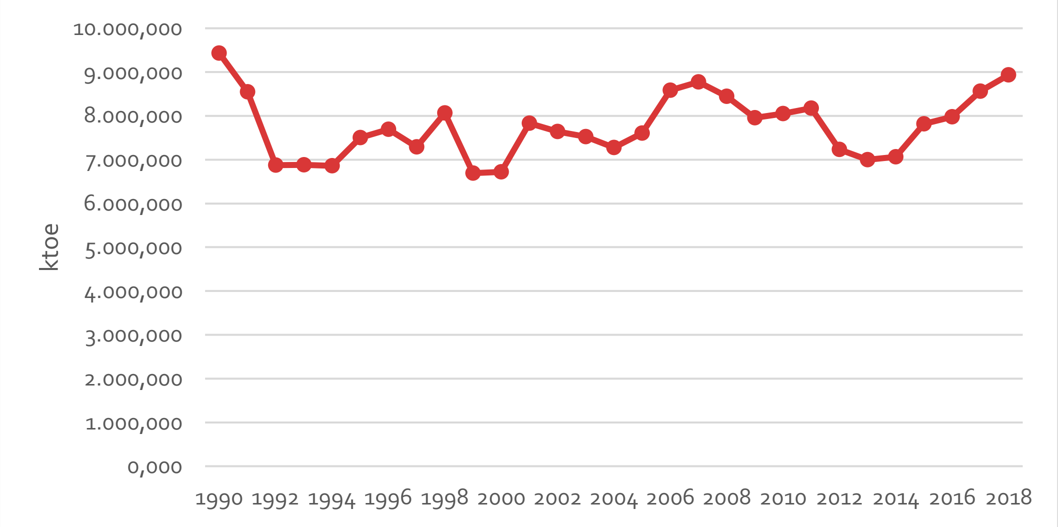

Figure 12 Oil and petroleum products available for final consumption 1990-2018, Romania

The Romanian refinery throughput declined between 1980 and 1990 but has remained relatively stable around 200-300 thousand barrels per day since the 1990s [33]. The refining capacity diverged with to the throughput during 2008-2019, indicating that there were capacities closures to better match the actual crude oil processed, see Figure 13.

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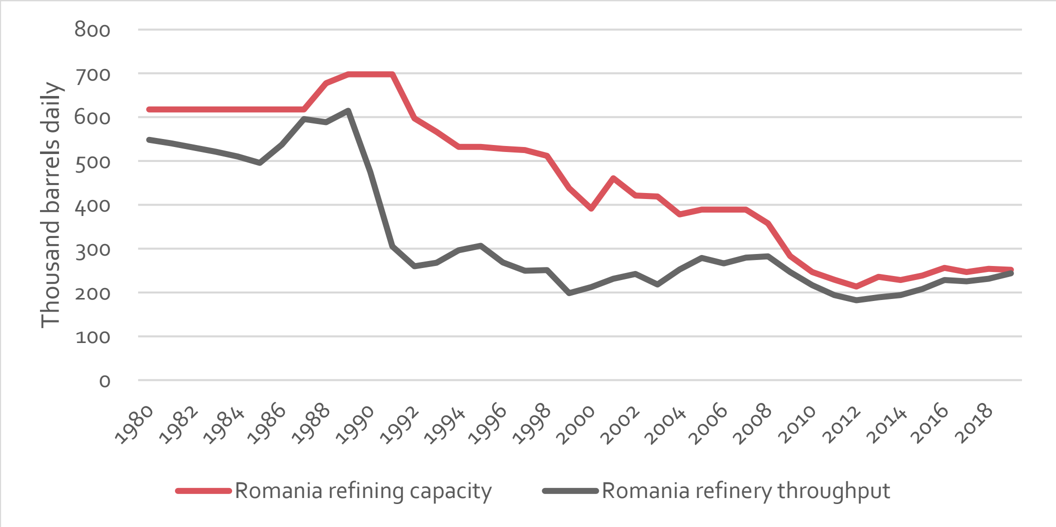

Figure 13 Romanian refinery capacity and throughput 1980-2019

Rompetrol Rafinare is part of KMG International Group (54.63% of the shares), but the Romanian state is also a main shareholder with 44.7% of the shares [41]. The company is one of the most important contributors to the state budget; in 2019 the total amount paid to the state was 1.6 billion dollars [42].

Rompetrol operates two refineries in Romania; Vega and Petromidia, which together make up 44% of the Romanian crude oil processing capacity [43]. The Petromidia refinery is the largest Romanian oil refinery and was taken into operation in 1979 [44]. In 2008-2012 the Petromidia refinery underwent a large modernization and capacity upgrade and now has a Nelson complexity index of 11.4 [45]. In 2014 a production optimization program was initiated to increase the yield of white products (gasoline, diesel and jet fuel), reduce technical losses and optimize the operational cost, and this program is still ongoing [42].

The Petromidia refinery is primarily processing Ural crudes and the main products from are fuels; mainly gasoline and diesel [43]. In the 2019 production plan Rompetrol expected that more than half of the petroleum products for the transportation industry would be sold on the domestic market [46]. The company is also one of Romania's largest exporters of petroleum products; with Bulgaria, Moldova and Georgia and other partners in the Black Sea region being the main markets [42]. The Petromidia refinery is also integrated with the petrochemical division of Rompetrol by supplying it with the entire needed quantity of polypropylene [47]. Rompetrol is the only producer of polymers in Romania and the main supplier of petrochemicals on the domestic market.

In [40] the authors commented that the Petromidia refinery is a small and complex coastal refinery exposed to imports (i.e. international competition). However, there were two constraining factors for international competition; (i) the Romanian government has a large share of the company and has marked it as a strategic asset for Romania and; (ii) regulatory issues might be a constraining factor for the region.

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6.3 Preem and St1: Swedish oil refineries

The Swedish consumption of oil and petroleum products has declined since the 1990s [39], as could be seen in Figure 14. This is mainly due to a decrease in the consumption of oil and petroleum products in the industry and for heating in buildings [48].

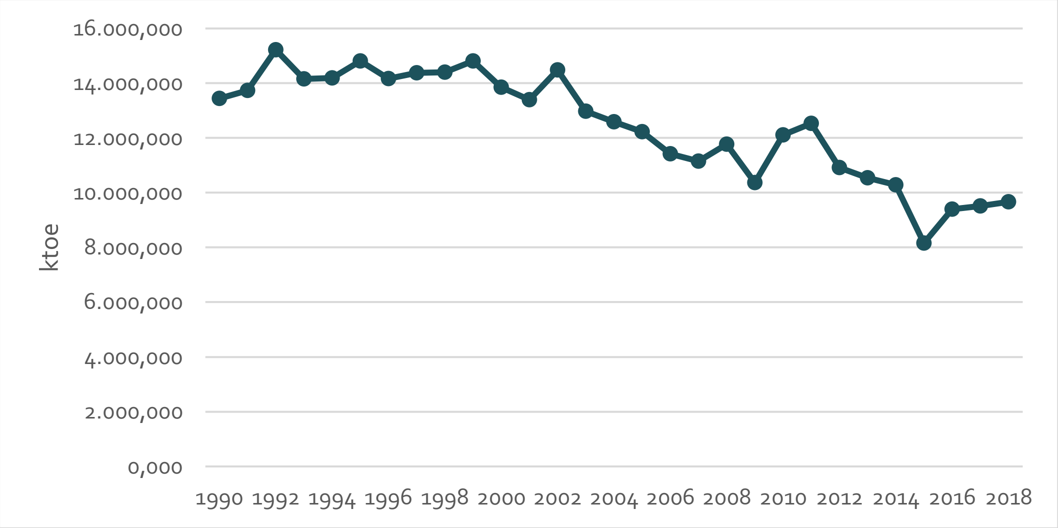

Figure 14 Oil and petroleum products available for final consumption 1990-2018, Sweden

The Swedish refinery capacity and throughput has remained relatively stable since the 1980s [33], see Figure 15.

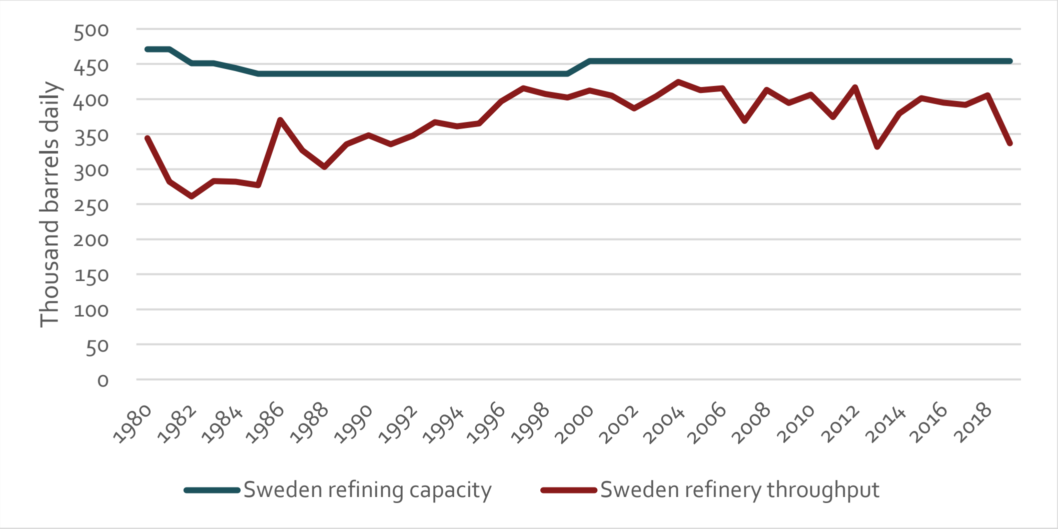

Figure 15 Swedish refinery capacity and throughput 1980-2019

Preem accounts for 80% of the Swedish refinery capacity and 30% of the Nordic capacity for refined petroleum products [49]. The company owns two refineries in Sweden; Gothenburg and Lysekil. The major part (60%) of the products is exported (around 60%), mainly to Northwestern Europe. The

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Gothenburg refinery has a technical capacity of 125,000 barrels per day, a Nelson complexity of 7.1 and produces mainly diesel, gasoline and fuel oil [50]. The refinery in Gothenburg processes mainly North Sea crude oil [51]. In 2018 Preem had 34.5% of the Swedish domestic market for diesel fuel, which made the company the largest diesel supplier on the Swedish market [52]. For gasoline, Preem had 18.4%, ranking the company in fourth place on the Swedish market. The Gothenburg refinery is also processing renewable raw material for the production of biofuel and has announced plans to expand the production of renewable diesel and jet fuel [53]. Today around 1% of Preem's fuel production is renewables, but the objective of the company is to increase this share to 15% in 2030 [54].

St1 Refinery AB is part of the St1 Nordic Group [55]. The St1 refinery in Gothenburg has an annual refining capacity of around 30 million barrels of crude oil and this level is expected to remain stable in the near future. In 2019 the refinery output was 23.9 million barrels. The refinery mainly processes North Sea crude oil but also works as a blending hub and mixes the oil refined in Gothenburg with fossil and biofuels from other refineries, mainly around the Baltic sea. The refined products include gasoline, diesel and other middle distillates as well as marine fuels and liquified petroleum gas. Most of the products are sold in Sweden, Finland and Norway. In 2018 St1 had 14.2% of the Swedish domestic market for diesel fuel, which made the company the fourth largest diesel supplier on the Swedish market. For gasoline, St1 had 18.4%, ranking the company in third place [52]. In 2022 St1 will start the production of renewable biodiesel [55]. In 2019 the net sales of renewable energy were 0.7% of the net sales. St1 claim that they aim to increase this share and the renewable strategy is mainly driven by 2030 environmental regulations planned in the Finnish, Swedish and Norwegian markets. In the 2019 integrated annual report, St1 is predicting that the business environment will continue to be challenging and volatile for the refinery industry.

In [40] Nivard and Kreijkes commented that both the Preem and St1 refineries in Gothenburg are coastal refineries exposed to imports, but that international competition is constrained by the integration with the local heat network in Gothenburg.

7 Pulp & Paper

The pulp and paper industry is experiencing a transformation as the demand is shifting away from graphic paper to higher-growth areas such as tissue paper and packaging. The global forest-products market has experienced volatility lately but is now expected to reach a stabilization of supply and demand. The demand is forecasted to grow in the long run and China has a significant impact on the market given their large share of the global demand for paper and board products. The forest supply is a constraining factor for new supply capacity, and the cost of wood determines the competitiveness of a pulp mill as the raw material is a large share of the costs. Spanish pulp mills have among the largest wood cost shares in the world, possibly making them vulnerable to changes in price. Currently most of the production of the both pulp and paper companies in SO WHAT is tissue paper for the European market, but Södra Cell is also experiencing an increased demand from Asia. Both Ence and Södra Cell have expanded their portfolios by selling biproducts (electricity, heat, biofuel etc.).

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7.1 The Pulp & Paper market

In 2014 the three main pulp producing regions were North America (38%), Europe (27%), Asia (18%) [56]. Out of the global pulp production, 42 % was from virgin fiber while 55 % from recovered fiber. New pulp milling capacity is being created mainly in South America (primarily Brazil), Russia, Asia (mostly Indonesia) and Northern Europe. A restricting factor in pulp milling is that the pulp mills based on wood fiber needs to be located fairly close to the sources (forests or plantations) to be economically viable. In China and Japanese markets, there is however a considerable use of imported woodchips.

The past years have been characterized by an increased instability in the forest-products market [57]. Companies are moving away from graphic paper into higher-growth areas. Despite a decline in global demand for graphic paper, according to [57] the paper and forest products industry is growing and is at the same time in transformation. Packaging is growing, as tissue paper and pulp for hygiene products [57, 58]. There is also a growing interest in pulp for textile applications as well as for other completely new applications [57]. China has a significant impact on the development of the demand on the market, given their global weight on the paper and board market, meaning that relatively modest changes in Chinese demand can have a significant impact on the market.

The raw-materials (fiber) side has seen some turbulence the past years but now seem to trend toward stabilization [57]. [57] argue that the midterm projections are likely to be favorable for the producers, as there is little new supply capacity until 2021-2022 and some production plants needs to undergo renewal upgrades. There are also challenges in expanding new supply due to constrained forest supply. The global pulp and paper industry is coming from a period with large investments [59]. Just as the authors of [57] anticipates, Swedish pulp producer Södra is predicting in their financial report for 2019 [59], that there will be very little added capacity during the next years but rather a stabilization of supply and demand and that prices will increase slightly.

The cost of wood is a factor that most often determines the competitiveness of a pulp manufacturing plant [60]. Globally, this cost-share varies and in 2019 the worldwide average cost of wood as a percentage of total pulp production cost was around 61%. Countries such as Germany, Canada and New Zealand was among the countries with the lowest wood cost share, while Japan, China, Indonesia and Spain had the largest wood cost percentages. According to the Wood Resource Quarterly, as cited by [60], the global wood fiber prices have fluctuated substantially during the past three decades. In the 1990's there was a downward trend and from 2002 to 2008 the prices for both softwood (BHKP) and hardwood (NBSK) climbed. Hardwood reached its record level in 2011 and softwood in 2008. Currently the prices are back on the same levels as in the mid-00's.

Since 2014, the European production and consumption of graphic papers have decreased, and at the same time increased for sanitary and household papers [58]. The production of packaging materials has increased, while the apparent consumption within EU of such paper products has decreased. In Europe, Finland and Sweden are the main pulp-producing countries [61].

In 2019, the prices on softwood pulp plummeted with 33 % compared to 2018 when they were on high levels historically [59]. Most of the pulp producers have a stable production and hence there was a large supply of pulp on the market. At the same time the general economic situation in Europe

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weakened and companies such as Södra Cell had to resort to other markets, such as Asia. [57] confirm that in Europe several producers have moved away from graphic paper to virgin-fiber carton board, which has led to an oversupply on the European market and a need for exporting the products.

7.2 Ence: Spanish hardwood pulp mill in Navia

There are 10 pulps mills and 70 paper and paperboard plants in Spain and the country is the sixth largest paper and pulp producer in the EU [62]. In 2018, 1.7 million tons of pulp was produced in Spain.

The Navia factory in Asturias, Spain, is Ence's largest production plant of eucalyptus ECF (Elemental Chlorine Free) pulp [63] in the BHKP (hardwood) segment [64]. The main application for the pulp is specialty paper [63], but most of the income from the pulp is generated from the tissue segment [65]. Ence is mainly selling the pulp on the European market. The Navia facility also generates renewable energy, with 77 MW installed capacity 519 GWh renewable energy was produced in 2018 [66].

In 2019 the company invested in a capacity expansion in the factory, enabling an increase in the pulp production by 80,000 tons per year [64]. As a result of the capacity expansion, but mainly also lower selling prices for pulp, the financial result for the pulp business of 2019 was lower than the previous year. In the end of 2019, the pulp prices reached the lowest point in 10 years, but the prices had bottomed out in the beginning of 2020. Ence is predicting that the pulp demand will continue to grow and that the demand will outgrow supply over 2020-2024, leading to an annual increase in 0,1 Mtonnes for Ence's two factories in Spain.

The renewable energy part of the company was increasing its result compared to 2018 and there are renewable investments in the pipeline for the company [64]. New biomass power plants were commissioned in the first half of 2020 to boost the energy generation by more than 50% in 2020.

7.3 Södra Cell: Swedish softwood pulp mill in Värö

Around 90% of the Swedish pulp production is exported, out of which more than half of it to the EU [67]. During 2019 China became the largest export market for Swedish paper pulp. Germany, which has been the largest trade partner the five years before that, remain to be an important market. Second to Germany is Great Britain. The covid-19 pandemic has led to a volatile pulp market, but the Swedish pulp production has increased just as the exports, mainly driven by an increased demand from the EU.

The pulp mill in Värö, Sweden has a production capacity of 700,000 tonnes per year [68]. The facility was completely rebuilt in 2016 and is now one of the largest softwood kraft pulp mills in the world. The main products produced at the plant is ECF paper pulps (Totally Chlorine Free, TCF, on request). Biproducts from the pulp mill are electricity, district heating and biofuels.

The Värö pulp mill is one of three Swedish pulp mills in Södra Cell; a business area within Södra group and is one of the largest pulp suppliers worldwide [59]. The three pulp factories in Sweden mainly produce softwood pulp, more specifically NBSK (Northern Bleached Softwood Kraft), which is used for tissue, specialty paper, packaging and print paper in Europe. 40 % of the pulp from Södra Cell is used for tissue. There is an increased demand from Asia, mainly China, on tissue and the company is increasing its focus on the Asian markets.

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In 2019 financial report, a number of risks have been highlighted [59]; out of which two are specific for the pulp and paper industry i) Climatic impacts and biologic threats to the forest supply; and ii) competition with increased production capacity and changes in demand as well as the supply and market price of raw material.

8 Cobalt & Germanium

Germanium and cobalt will be needed in significantly larger volumes globally, and specifically for low-carbon technologies (e.g. rechargeable batteries) and high-technology devises (e.g. optical fibers, 5G). China is dominating the market for refined cobalt (most of it imported from Democratic Republic of Congo) and germanium. Europe has a high import dependency, and due to their economic importance of cobalt and germanium these have been listed as critical raw materials for the EU. Umicore is investing in their recycling capacity, driven by three megatrends; resource scarcity, demand for cleaner air and electrification of vehicles. The main competition is from cheaper cobalt "unethically sourced from artisanal mining", e.g. in DRC.

8.1 The Cobalt & Germanium market

Cobalt and germanium are specialty metals [69]. These are used in small volumes and often essential for the production of high-technology devises and low-carbon technologies. Both cobalt and germanium will be needed in significantly larger volumes to attain climate goals and specifically for the technologies enabling a transition of the energy system. For example, it has been estimated that the demand for metals for battery energy storage (including for transportation) will increase by 1000% by 2050.

Since the beginning of the 2000s the pressure on raw material commodity markets have increased with the growing demand from emerging economies [70]. With the increased pressure, export restrictions on the exports of minerals and metals have become more frequent. The share of primary production subject to export restriction in 2014, was around 75 % for both cobalt and germanium.

Cobalt is mainly sourced from virgin sources and recycling is not yet so developed [71]. Most of the world's supply of cobalt is from the Democratic Republic of Congo (DRC) and the country contributes to a share of 60-70 % of the cobalt worldwide [72, 73]. China dominates the market for refined cobalt, most of it produced from cobalt imported from DRC [74]. In 2016, the Chinese market share of refined cobalt was 48% (an increase in with 23 percentage points since 2008), and 68 % if refined production is considered [69]. China is also the main global consumer of cobalt and the rechargeable battery industry represent around 80 % of the Chinese cobalt consumption. The global cobalt demand is dominated by the rechargeable batteries segment; key sectors include Li-ion batteries for electric vehicles and other applications (laptops, PCs, smartphones etc.) [75]. Cobalt has been identified as one of the bottle neck materials critical for battery storage manufacturing [76]. In [77] Peters et al. estimated that the demand for cobalt from a future electrified global vehicle fleet will exceed the reserves if no recycling is happening.

The available world resources of germanium are associated with zinc and lead-zinc-copper sulfide ores [74]. China is dominating the market for germanium with a 65 % share of the global refined production in 2019. Germanium is mainly used in optical sector applications, in products such as optical fibers, infrared optics and light emitting diodes (LEDs), but to some extent also in multi-junction solar-cells [70]. Fiber-optic cable manufacturing was about one-third of the global

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consumption in 2019 and the development of the demand is closely linked to 5G roll-out and cable installation by telecommunication companies [74]. Globally, 30% of the total germanium consumed is from secondary production, and during the manufacture of most optical devices 60 % of the germanium is routinely recycled [74].

As metals are a globally traded commodity, Europe is exposed to significant levels of international competition [69]. The EU primary production as a share of the global production is around 10% for cobalt and below 0.5 % for germanium. The import dependency is high; 32% of the cobalt and 64% of the germanium consumed in the EU is imported [78].

EU has a very small share in extraction, smelting and refining of non-ferrous base metals (from which cobalt and germanium is a by-product) but is a world-leader in recycling with a 24 % market share [69]. The EU has high metals recovery and recycling rates for metals and Europe is a net exporter for almost all types of non-ferrous metal scraps. The main destination market for the metal scraps is Asia, particularly China. In 2016, the share of EU secondary production, e.g. production from recovered and recycled material, of cobalt was 32% of the global secondary production. The end-of-life recycling input rates (EOL-RIR, the contribution of recycling to the total demand) in the EU-28 of germanium is 2% and 35 % of cobalt [70].

Due to the economic importance and risk of supply shortage of both cobalt and germanium, they have been listed (together with 25 other materials) as critical raw materials for the EU [78]. The list of critical raw materials is supporting in incentivizing recycling and mining activities, support when trade agreements are negotiated and in developing research and innovation actions.

8.2 Umicore: manufacturer of high-tech materials based on cobalt and germanium

The Belgian demonstrator Umicore is a multi-national materials technology and recycling group, more affected by global development than the Belgian domestic market. The site in Olen, Belgium is focusing on recycling, clean technology, R&D and production of high-tech materials based on cobalt and germanium [79]. The company highlights three megatrends as their business drivers: resource scarcity, demand for cleaner air and the electrification of vehicles [80].

According to the 2019 annual report of Umicore [81], the revenues in the business unit Energy & Surface Technologies, of which the Olen site is mainly part of, the revenues decreased during 2019 mainly due to depressed cobalt prices. In 2018 the cobalt price reached historically high levels, but during 2019 it more than halved compared to 2019. Despite the reduced revenues in the business unit, Umicore has continued to invest in the growth of the unit. Among the investments in 2019 was a new Process Competence Center in Olen. The Olen site was also approved as the first Responsible Minerals Initiative cobalt refinery, followed by the accreditation of the newly acquired cobalt plant in Finland in 2019. Cheaper cobalt "unethically sourced from artisanal mining" [81] continue to impact the performance of the business unit.

9 Carbon Black

The Asia Pacific region is dominating the global market for carbon black, both in terms of consumption and production. The industry is dependent on the development of the tyre and

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automotive industry as most of the carbon black produced is used in tyres. The demand for carbon black is strong and prices are slightly increasing. Imerys specialty products, used for example in Li-ion batteries, produced in Willebroek are experiencing an increasing demand as well.

9.1 The carbon black market

The most common application for carbon black is as an additive in tyres [82]. In 2017, around 9 million tonnes of carbon black was processed in tyres worldwide. This can be compared to 2011, when 7.8 million tonnes were consumed for tyres. Rubber products for industry and construction (such as conveyor belts, roll coverings, cables etc) ranked second, and the use of carbon black as a black pigment currently represents a very small share.

In 2017, the Asia Pacific region consumed 62% of the carbon black worldwide [82]. This market share is expected to increase to about 65 % by 2025. China is the largest consumer, with a consumption of 4.7 million tonnes in 2017. The North American market was second largest in 2017, followed by Western Europe.Asia Pacific is also leading the production worldwide [82]. In 2017, more than 64 % of the production took place in this region, and the share is expected to increase thanks to an increase in production capacity. Second in production, well after Asia Pacific, is North America followed by Eastern Europe.

As the main application for carbon black is tyres, the industry is dependent on the development of the tyre and automotive industries. This has been evident with the tire and automotive plants shutdown during the covid-19 outbreak in 2020, which has been predicted to impact the carbon black industry with a 11% decline in the global carbon black market in 2020 [83].

Previous to the covid-19 crisis, the main challenges for the black carbon industries have been short supply, logistics problems, difficulties in increasing capacities, competition from silica (as reinforcement in tyres) and cost of environmental compliance (i.e. the U.S. EPA surcharge for North American consumers) [84]. However, analysts have claimed that the demand for carbon black is strong and robust and the prices for specialty and rubber black carbon are slightly increasing.

The carbon black market in Europe is expected to expand at a growth rate of 4.6% annually between 2019-2024, according to Research and Markets as cited by [85]. The production and sales of cars and commercial vehicles in Europe is expected to increase, and hence the use of carbon black. Germany, the fourth largest vehicle producer globally, is expected to be the main market for carbon black in Europe. There is also an increasing demand from other end-use industries that is expected to drive the market for carbon black.

9.2 Imerys: manufacturer of carbon black products

The Belgian demonstrator Imerys Graphite & Carbon belongs to the multi-national Imerys Group, which is focusing on mineral specialties for the industry [86]. The carbon black plant in Willebroek, Belgium, opened in 1982 and produces specialty-type carbon black, mainly used by the conductive polymer and battery industries [87]. In 2013 the capacity was doubled in the plant in Willebroek to support an increasing demand from the mobile energy sector [88]. The renewable energy segment was 5% of the revenue in 2019, and the company held the first place in market position in conductive additives for Li-ion batteries and graphite for alkaline batteries. The plan is also to grow the sales of graphite and carbon black in Li-ion batteries.

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