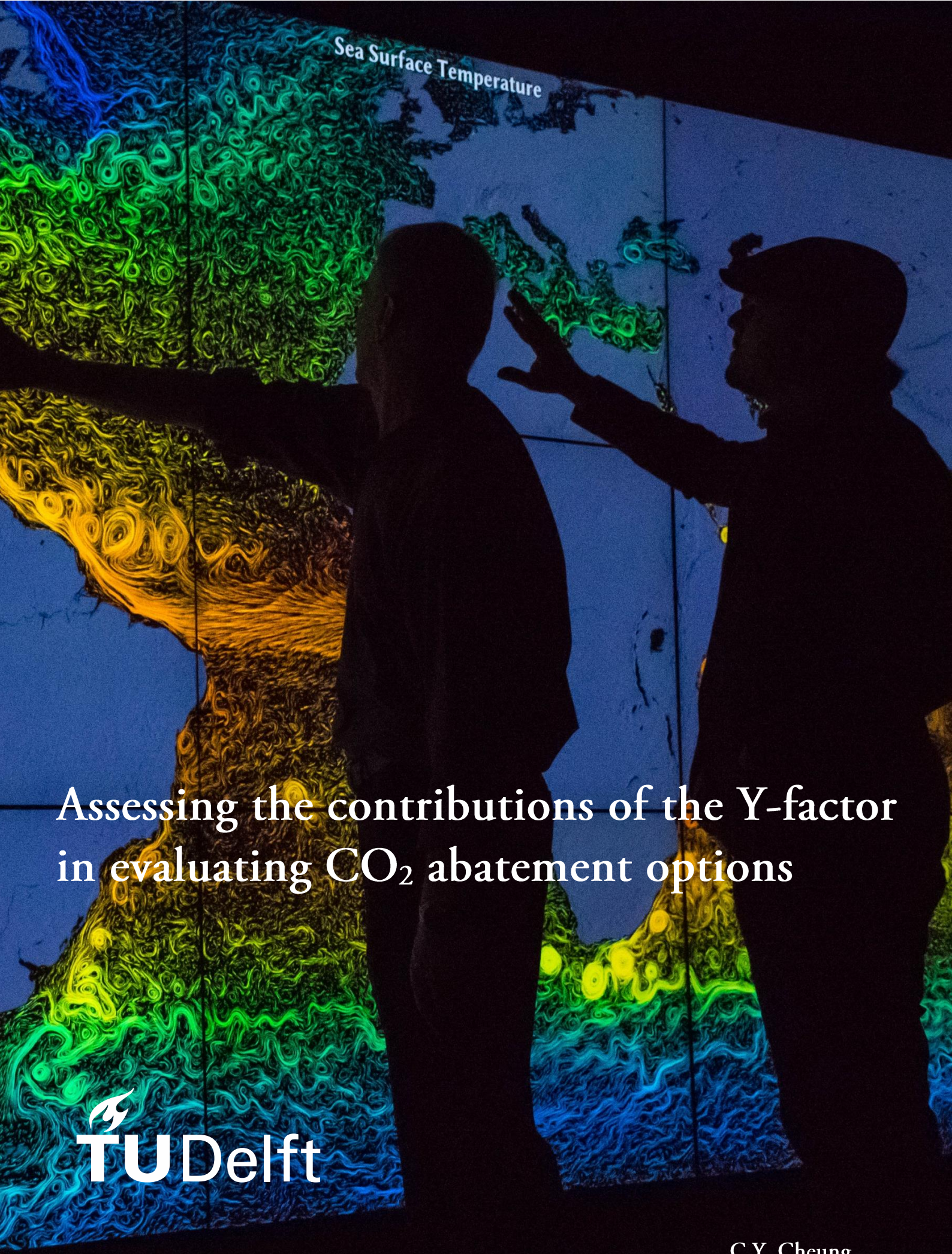

Assessing the contributions of the Y-factor in evaluating CO_2 abatement options

TU Delft

C.Y. Cheung

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Cover art:
Leonardo DiCaprio visited Goddard Saturday to discuss Earth science with Piers Sellers in the documentary “Before the Flood”. (By NASA Goddard Space Flight Center from Greenbelt, MD, USA Creative Commons)

Assessing the contributions of the Y-factor in evaluating CO_2 abatement options

By

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in partial fulfilment of the requirements for the degree of

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in Complex Systems Engineering and Management

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Preface / Acknowledgement

It has been quite a journey, and I couldn't have done it without the support of my family and friends. In 2012, I experienced a big turn of events. I was fortunate enough to be blessed with my family and friends then, and as of today, I can't give thanks enough. These past years, and since the start of this thesis in December 2017, I have also made some noteworthy friends, and I am so grateful for them. They gave me new perspectives, new options and ways to go about sometimes the most mundane tasks of life. They have shown me the bigger picture, but also the smaller picture called the graduate's project. For someone on the outside, such perspective-creating deeds would have seemed like small and inconsequential gestures, or they would have seemed like acts or words of serendipity. However for me, they were of great relevance, one could even say an accumulating force of relevance. It has become a force of its own by now and an appetite of its own. An appetite for the small and the big, for the simple and the complex, for the old and new. I feel like parts or elements of that force have blended into my identify as of now. I am not sure if I can nurture or keep this force in check, but I sure know I want it close. And if it ever fades away, I will be ready, because I think I know where I can find it again.

For the most recent part of this journey, I want to thank my graduation committee first and foremost. I want to thank dr. ir. Ivo Bouwmans for taking me along a road I wasn't too sure of taking. I want to thank him for taking a leap of faith with me. I want to thank Ivo furthermore for his openness and optimism, as sometimes for some reason he just knew, even before I realized myself, that his openness and optimism were just what I needed.

I want to thank dr. ir. Émile Chappin for his guidance along the whole way. His consistency in his methods and approaches helped me see through some of the most complex matters in this thesis. I have always enjoyed the constructive feedback and visual artwork on the whiteboard with Émile. I might never forget the joyous moments of Émile drawing a bathtub as a visual for supporting his feedback. And as such, I will certainly take those moments with me, and hopefully that skill too, for the rest of my life.

I would also like to thank the last member of my graduation committee, Els van Daalen. As the second supervisor, she would provide critical feedback, and so she did, and I appreciate that greatly as she also did that with kindness. I have to thank Els also for some fortunate doorstep and hallway moments. I appreciate that a lot and I feel honored to have her on my graduation committee.

Second, I would like to thank the 22 anonymous interviewees for this thesis. Due to some sensitivities, their names are not made explicit. However, their input have been invaluable and this thesis would not have been possible without their contributions.

Moreover, I would like to thank the people at the faculty. I would like to thank Jos Timmermans for his invitation to his stories as it helped me be prepared for deep uncertainties. I would like to thank Marja Brand for her attentiveness. I would like to thank Jolien Ubacht for her experienced wayfinder's role around the faculty.

Finally, I would also like to thank the Writing Club for letting me catch a glimpse of their (novel) writing passion and for developing my taste for mint tea. Next, I would like to thank my Badminton Club for showing me the importance of timing and discipline. I would also like to thank my Smart Study club and Poker Club for keeping me sane and being the outlet for my thesis frustrations. Special mentions go to Boudie Rijkschroef for his cultural research insights, Alexander for reaching out to me with tools that I might need, Rosa for her companionship in the "Write-a-thon", Wai for the "thesis-retreat", Sherry for her patience and her planning skills, Melissa and Isabel for their catchy and relevant mottos. Thank you Yang, Claudio and Radha for the typo review, and I am grateful for my (ex)roommates for reminding me to eat, sleep, work and repeat. And I am sure I missed some important friends too, I hereby thank thee! Last, but not least, I want to thank my mom, dad and sister for their unconditional love and support.

CY (Chun-Yu) Cheung
Delft, August 2018

TU Delft

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Executive summary

In 2015, the Paris Climate Agreement was signed by more than 195 nations. One of the new formalized agreement is that nations should draft INDCs (Intended Nationally Determined Contributions). In these INDCs, CO_2 abatement options and other climate actions and commitments of a nation are written and published for all to witness. The idea is that if all of the world's nations contribute in one way or another, the transition from a high carbon economy to a low carbon or zero carbon economy, could become a reality. However, some see the INDCs as merely "paper tigers"; documents with farfetched ambitions. One of the ways to improve this situation, and to take steps towards agreeing to a legal framework is to have open and constructive dialogues with the representative policy makers of the nations. In organizing such a series of dialogues, the highest ambitions of the nations should be taken seriously as well as the respective capability of the nation given different national circumstances. In such policy situations, there is a need for a more in-depth look into the various national CO_2 abatement options.

One of the method to examine abatement options in-depth is by using the Marginal Abatement Cost Curve (MACC). This methods looks into the potential of CO_2 abatement options from an economic point of view. However, scholars argue that the MACC should be used with caution and that the method should be complemented with a non-economic perspective. This thesis focused on such a non-economic method, the Y-factor. The Y-factor focusses on the Multi Actor (MA) complexity, the Physical Interdependencies (PHI), and Behavioral (Beh) elements as indicators of why abatement options would fail or succeed as opposed to a compact monetary value indicating an option being cost-effective or expensive. The method is in its proof of concept stage, and empirical evidence is lacking. The thesis objective is to contribute to the body of knowledge of the Y-factor by gathering empirical evidence that may underpin the Y-factor in its endeavor to create a better understanding of CO_2 abatement options. The main research question is therefore how the Y-factor can contribute to a better understanding of CO_2 abatement options. The research methodology is to conduct multiple case studies of CO_2 abatement options in the Netherlands. Six case studies have been constructed out by collecting data using a semi-structured interview approach.

The first contribution that this thesis has made is, by expanding on the understanding of the Y-factor and abatement options through the theoretical lenses of transition and transition management theories. The rationale is that abatement options are part of a climate system in transition, which may be perceived as a problem of managing a socio-technical system. The three indicators of the Y-factor, Multi Actor (MA), Physical Interdependencies (PHI), and Behavior (Beh) may each be related to transition theories as follows. MA may refer to actors from the multiple level perspective (MLP), actors in the transition arenas (TA) and in between regimes and niches. Abatement options with the right actor in the right places may be in transition. PHI may refer to dependencies as systems embeddedness and subsystems interactions. In transitions, system and subsystems may embedded, or subsystems may interact and disturb other subsystems. For example, abatement options in transition may be embedded in the physical gas infrastructure or may disturb the direct neighbors next door. Finally, the focus on Behavior in the Y-factor can be understood as being requirements for niche developments. In transitions, niches are the outcome of the aggregated efforts or collective action from technology entrepreneurs, a certain organization acting just a bit outside the norm, or the average Joe. If the behavioral conditions are right and if there is an opportunity, abatement options may become breakthrough niches.

The second contribution that this thesis has made, is by testing the Y-factor in practice and as a tool for gathering empirical data. By using the Y-factor as an assessment framework in the context of semi-structured interviews, it has been shown that the Y-factor is capable of creating case studies on a variety of abatement options. Six case studies have been carried out in six sectors, these are the Heavy Industry, the Build Environment, Energy Production, the Forestry, Agriculture and the Waste sector. The components of the Y-factor, from a

transition perspective, has been understood by practitioners and experts in practice. The Y-factor has also been found useful for creating case studies in such a diverse environment. All categories of the Y-factor have been found useful for creating the case studies.

The third contribution of this thesis is that the Y-factor can be used for comparing abatement options. First, this is shown by comparing the abatement options using a quantitative approach, the scoreboard overview showed few unexpected values, and in observing the narratives representing the categorical scores, underlying patterns may be present. Second, the narratives or the patterns of each abatement options are compared with transition theory. As the Y-factor provided a structure for the narrative, a synthesis of patterns were proposed for each category. Then, these patterns were compared with transition theories. In this comparison, the Multi Actor category stands out as it has been found to be the best compatible with transition literature. The Physical Interdependency and Behavior categories have been found to be harder to reconcile with transition literature. Third, the abatement options were compared using the three interview perspectives. The scores of the Y-factor were grouped in three perspectives, and compared in the context of the six cases. The perspectives comparison showed that some Y-factor could be over- or underestimated, but the data sample is too low to suggests implications for the analyses in this thesis. Last, but not least, the Y-factor has also been compared with the MACC, which is characterized by a more economic approach. The findings of comparing the six cases with both the Y-factor and the MACC, suggests that it is likely that the Y-factor is able to complement the MACC method in evaluating CO_2 abatement options. In comparing the two methods, some cases (the Housing and Green Gas cases) have been found to be more likely to be suitable for the Y-factor, while other cases (the Waste, Forest and the Wind cases) are more likely to be suitable for the MACC. such as the Y-factor than with the MACC. The comparison also revealed that this outcome is stronger for the Housing case than for the Waste, Green Gas, Forest and the Wind case.

The findings of this thesis need to be put into the wider perspective. First, a subset of transition theories is used in the wider transition literature. Further research within transition literature is recommended, and research in the direction of system learning at the sector scale is suggested. The Y-factor is also not related to theories outside the transition literature. Two suggestions for further action are made in the field of behavioral economics and institutional economics. This may be most relevant for the Behavior and Physical Interdependencies categories respectively, due to the empirical findings.

Second, the findings are to be put into the chosen research perspective for this thesis. In conducting the analyses, the CO_2 abatement options and their context are simplified using the systems perspective. The findings are also time-sensitive and need to be put into the perspective of a certain policy maker. While a specific policy analysis is missing in this thesis, the Y-factor is studied using the same context and the same wider decision making process assumed of the MACC. Under this assumption, the findings of this thesis only has policy implications for the decision makers of the MACC. However, the policy implication may need to be researched, as other methods and policy instruments are not compared with in either efficacy or efficiency in this thesis. It should also be noted that there is no (policy) implications for MACC analysts on the basis of this thesis.

The third relates to methodological limitations of the research. These limitations are derived from the case study as a research method, and further research is needed for the selection of the interviewees, the Y-factor as a structured for interviews, and the Y-factor scores. The Delphi method is suggested as a direction for future research, as well as a factor analysis, a type of multivariate analysis.

1. Introduction of CO_2 abatement options

"Which models to construct, which alternatives to compare, and whether the study outcome is to be a solution feasible under defined uncertainties, a formal optimization, or a presentation of alternative possibilities, are all decided in the problem-formulation phase."
Peter Checkland, 1985

"We will move to a low-carbon world because nature will force us, or because policy will guide us. If we wait until nature forces us, the cost will be astronomical."
Christiana Figueres, 2015

1.1 Abatement options for the transition to a low carbon economy

The challenge CO_2 abatement options
Various policy makers around the world are tasked with meeting emission targets. For example, the ozone emissions for the parties under the Montreal Protocol (signed 1987) or the nitrogen oxides (NOx) and carbon dioxide equivalents (CO_2e) under the Kyoto Protocol (signed 1998) and the Paris Agreement (adopted 2015). In the Kyoto Protocol, around 192 parties (countries, nations and other UN member states) agreed to a broad outline of emission targets. The parties under the Paris Agreement, commonly seen as the successor of the Kyoto Protocol, agreed to more specific emissions targets. For example, the European Union and 28 of its Member States pledged collectively to a binding target of an at least 40% domestic reduction in emissions by 2030, while Brazil and China respectively pledged 37% reductions below 2005 levels in 2025, and 45% from the 2005 level by 2030. To meet emission targets, parties under the Paris Agreement also had to identify abatement options and communicate their policy options internationally. The majority of the parties communicated their national climate options by drafting a document called "Intended Nationally Determined Contributions" (INDC). The United Nation Framework Convention for Climate Change reports and published these INDCs in accordance with the Paris Agreement (UNFCCC, 2015).

Governing the progression of abatement options over time
In the Paris Agreement, the process that has been put forward is that the 192 parties (and counting) are to report and update on their Intended Nationally Determined Contributions (INDCs) "every five years regardless of their respective implementation time frames" (UNFCCC, 2017, p. 1). In this respect, there is a concrete sense of urgency for each party. The parties are to report on their previous commitments and make progress every time

according to article 3 and 4 of the Paris Agreement (see exhibit 1). The international agreement is to better define the INDCs every five years with the aim that the parties may have more confidence in their commitments over time and that they may be transformed into Nationally Determined Commitments (NDCs) as soon as possible, in the light of the different national responsibilities, capabilities and circumstances. The first INDCs are reported back in 2015 and in 2020 and beyond, it is expected from parties to have their INDCs transformed into NDCs and communicate it in the forthcoming Conference of Parties (COP) organized by the UNFCCC.

Article 3
As nationally determined contributions to the global response to climate change, all Parties are to undertake and communicate ambitious efforts as defined in Articles 4, 7, 9, 10, 11 and 13 with the view to achieving the purpose of this Agreement as set out in Article 2. The efforts of all Parties will represent a progression over time, while recognizing the need to support developing country Parties for the effective implementation of this Agreement.

Article 4
Each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Exhibit 1 – Excerpts of the 2015 Paris Agreement

1.2 The role of MACC for CO_2 abatements options

To identify and evaluate viable abatement options (or the INDCs), policy makers may make use of the Marginal Abatement Cost Curve (MACC). The MACC is used by different countries to help in identifying (Costa Rica) and evaluating (Philippines; Macedonia) abatement options (UNFCCC, 2015). The MACC is not limited to the climate change domain and can be applied to the transport and electricity domain. The earliest application dates back to 1980s (Kesicki & Strachan, 2011). The MACC have become popular in the climate change domain, largely by the works of McKinsey & Company between 2007 and 2009, as they have produced "14 cost curves for different countries and a global cost curve" (Kesicki & Strachan, 2011, p. 1196). In the McKinsey report of the global cost curve with the title "Pathways to a low-carbon economy", the authors hope that these analyses "will serve as a useful starting point for discussions among companies, policy makers and academics on how best to manage the transition to a low-carbon economy". (Naucler & Enkvist, 2009, p.19).

The usefulness of the MACC lies in its quick overview and how the MACC curve sorts the abatement options by stacking the options from left to right based on increasing cost per tCO_2e, see figure 1. Each bin or bar of the histogram represents an option. In this overview, the individual bars are not labeled for illustrative reasons. The bars stacked on the x-axis, the accumulated width of the bars, therefore represents the abatement potential. The length of each bar is the calculated cost for each tCO_2e option. For example, if a country wants to reach a target of 20 $GtCO_2e$ per year, then all options to the left should be considered at least. A particular feature is the area below the zero y-axis at the far left of the graph (see key area number 1 in figure 1). This area contains the abatement options with "negative" abatement costs. The negative cost implies and assumes that abatement options will occur in the market given their estimated economic net profit (high benefits, low implementation costs and money saved in CO_2 rights). In the graph, the policy example of "1. Energy efficiency regulation" is shown and the assumption is that this type of abatement option will eventually pay back itself as depicted in the graph with negative abatement costs.

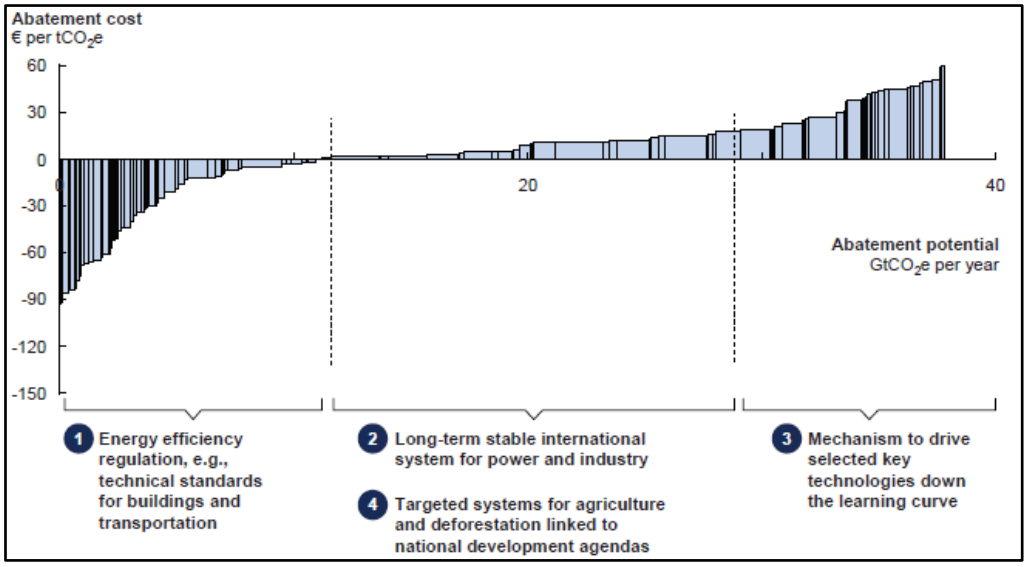

Figure 1 – Example MACC template from (McKinsey, 2009)

1.3 The challenge of MACC – the knowledge gap

1.3.1 The lack of insights in non-economic factors

In the MACC, the CO_2e price per ton (on the vertical axis) is used to show possible feasible abatement options for policy makers wanting to reach a certain target. It is worth noting that given its assumption, the MACC should not be used in isolation to decide upon what "price regulations to take or how aggressively CO_2e targets should be set" (McKinsey, p. 56). These are political decisions, and therefore needs to go under critical assessments, be subjected to democratic reviews and considered in “conjunction with other non-climate related political priorities” (McKinsey, p. 56). Some economists (McKinsey, p. 41) question the validity of the MACC in being useful in evaluating the feasibility of policy options. For example, the economists argue that if the net economic benefits are positive, referring especially to the abatement options at the bottom left side of the MACC, consumers and entrepreneurs alike would have captured them already. In response, experts of the MACC (McKinsey, 2009, p. 41) argue that “a range of market imperfections act as a barrier, and disincentive and hinder” some of these abatement options. Three market imperfection examples are given by these experts: a “lack of awareness”, “agency issues” and “financing hurdles and rapid payback requirements”. The experts emphasized that “a net economic benefit does not mean that they [abatement options] are easy to realize” (p. 41). Other scholars “call for caution” (Kesicki & Ekins, 2012), and comment on the “use and misuse of the MAC curves” (Vogt-Schilb & Hallegatte, 2011). One of the challenge of the MACC can therefore be defined as overcoming the lack of insights of these “non-economic” (p. 21) factors to complement the MACC.

Table 1 – Limitations and shortcomings of the MACC

Limitations and shortcomings to the MACC	**Author, year**
“a range of market imperfections”; such as “lack of awareness, agency issues, and financing hurdles and rapid payback requirements”.	McKinsey, 2009, p. 41
Cautious advised when interpreting MAC curves, should consider the “non-financial costs and be aware of the important uncertainties and underlying path dependencies”. (p. 219) “A system-wide approach is needed” that will include “path dependencies, important behavioral interdependencies, interactions between measures, and intersectoral and international interactions” (p.233)	Kesicki & Ekins, 2012

need to account for “inter-temporal dynamics” and “inertia”, in the form as in cost in time.	Vogt-Schilb & Hallegatte, 2011
Especially the net negative cost is used inappropriately, and the suggestion is “a simple approach of maximising the total benefit of the action instead”.	Ward, 2014

In the synthesis report by the UNFCCC, it is noted that no assumptions have been made on the likelihood of the INDCs being exceeded or implemented at all. The UNFCCC assume that “the parties [countries signing the agreement] will achieve in full the level of emissions implied in their INDCs” (UNFCCC, 2015, p. 21). This suggests that, while making this assumption may be justifiable for the UNFCCC, it may not be justifiable for individual parties to make this assumption, as parties have agreed to the responsibility for the proper policy execution of their communicated intended nationally determined contributions. It would be valuable for the UNFCCC or other policy makers to know the feasibility or likelihood of the communicated contributions from a more in-depth perspective.

1.3.2 The societal relevance

The wider societal question of this thesis on how to contribute to a better understanding of abatement options. The MACC is but one way to gain a better understanding of the abatement options. For some policy makers, the INDCs are only plans and ambitions. Strong and robust steps are to be made to follow those plans through. For UN policy makers, there is a need for understanding the climate actions from the perspective of “progression”, as stated in article 3 of the Paris Agreement. The numbers of climate actions in the communicated INDCs and its related policies could be a great challenge in the context of keeping track of the progressions over time. Having insights into different options to monitor this progression may help both the UN and the parties to choose between the most suitable policy instruments and method for monitoring. On a less global level, national policy makers tasked with the policy implementation of CO_2 abatement options for the nation and their sectors may also find this research useful. The thesis may help in facilitating additional constructive dialogues that show the external forces that are at play for such climate policies and its implications nationally. Such dialogues can be held between ministries operating at a national level, between ministries and sector representatives or within the sector and its industry leaders.

1.4 The Y-factor to complement the MACC

To complement the MACC, scholars have discovered several limitations and shortcomings and offered suggestions for possible solution, see table 1. One interesting way to complement the MACC is nicknamed the Y-factor (Chappin, 2016). The Y-factor is composed of 13 subfactors within four categories: costs and financing, multi-actor complexity, physical interdependencies, and behavior. The results of the Y-factor can also be presented in a curve similar to that of the MACC (see appendix A). In Chappin (2016), the Y-factor curve has been found useful for complementing the MACC. The order of abatement options in the curve produced by the Y-factor, is different than that of the MACC. This suggests that the Y-factor may help explain why some of the abatement options do not materialize despite having a net economic benefit according to the MACC. However, the Y-factor is still a “proof of concept”. The categories and the subfactors used remain to be unclear as why they would better explain why some abatement options would not materialize. For example, one of the subfactor is “different type of actors” under the category of “multi-actor complexity”. The Y-factor posit that if the “different type of actors” increases, the “multi-actor complexity” increases. Evidence to back up both the relation between the subfactor and the category is lacking, as well as evidence for backing up “multi-actor complexity”-category relation with the Y-factor itself. The assumption is that “more types of actors” would increase the abatement options project complexity or engineering difficulties, and the assumption is also that more “multi actor complexity” could be the reason *why* (the Y-factor) abatement options would be delayed or

hampered in their implementation. There is no evidence as why more “types of actors” wouldn’t decrease the complexity or difficulty of the abatement option. A theoretical underpinning and a concrete demonstration of the Y-factor in practice could help build up evidence for the Y-factor and therefore complement to the MACC methodological, but also give insights as why abatement options would fail or succeed.

1.5 Research objectives and research questions

Based on the preliminary examination of the CO_2 challenge, and with a specific focus on evaluation methods such as the MACC and the Y-factor, the argument is that it is interesting to research and build up a body of knowledge for the Y-factor in the context for abatement options. Therefore, the following main research question is composed for this thesis:

- **How can the Y-factor contribute to the understanding of the CO_2 abatement options?**

The following research questions are chosen to answer the main research question in threefold:

RQ1: How does the Y-factor relate to theories, more specific transition theories?
RQ2: What is the applicability of the Y-factor on a variety of CO_2 abatement options?
RQ3: How can CO_2 abatement options be compared by means of the Y-factor?

In the following paragraphs, the three research questions are elaborated on its relevance and in what way and with what research method the research question can be answered.

RQ1 How does the Y-factor relate to transition theories?
The first research question relates to how the Y-factor is broken down and conceptualized. In figure 2, a graphical representation of the Y-factor is shown. In the examined papers and the proposal of the Y-factor, it remains unclear of what the categories and the subfactors mean exactly. In this research, the aim is to contribute to the Y-factor by researching its relation with theories from scientific literature. The main research method here is a desktop search and a literature review. The tools for the desktop review is Google and for the literature review Google Scholar and Scopus.

A preliminary desktop search (see appendix B) for useful theories using the keywords from the Y-factor resulted in a focus on transition theories. The desktop search resulted in a divergence of known and unknown scientific fields and theories, such as behavioral economics, behavioral finance, land economics, decision making, complex networks, multi actor implementation, transition management theory, new institutionalism, game theory, cognitive-behavioral therapy, among others.

In the literature review, theories of transition and transition management seem to be useful for the Y-factor. In the introduction it has been stated that parties want to go to a low carbon economy. The McKinsey report of the abatement cost curves refers to a “pathway to low carbon economy”. First, the choice to focus on “transition” makes sense, as the movement or the path from high to low may be seen as a transition. Second, transition management has great diversity, as mentioned in the multiple case study of Loorbach & Rotmans (2010), and is able to handle the variations of abatement options for the transition of a whole economy. This is relevant as the McKinsey report categorized 10 sectors for abatement options, ranging from energy to forestry, aiming to capture the whole economy. In chapter two, more reasons are provided from a research perspective for why this is a sensible choice given the problem scope of the introduction.

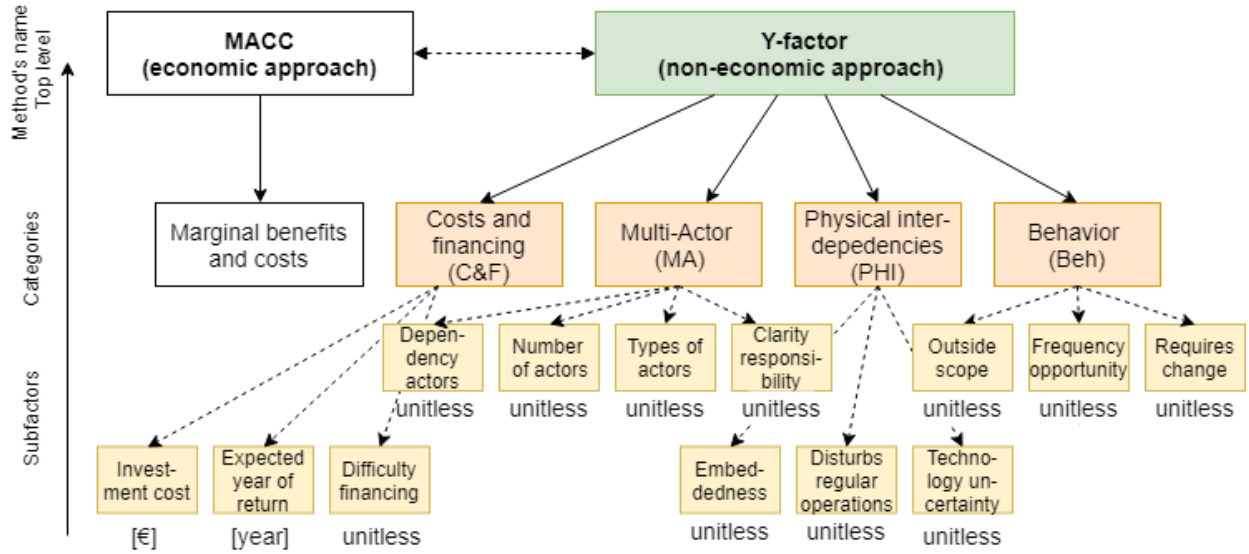

Figure 2 – A breakdown of the Y-factor as envisioned in Chappin (2016)

RQ2: What is the applicability of the Y-factor on a variety of CO_2 abatement options?

To get a better understanding of abatement options through the Y-factor, applying the Y-factor in practice could help. However, the Y-factor, in its proof of concept, is not fully designed for actual data gathering of abatement options. The research question is explorative in nature and aims to go in-depth into abatement options by means of the Y-factor, i.e. how could the Y-factor help in identifying reasons for abatement options to fail or succeed? The reasons depend on the context of the abatement option and could be time-dependent. As case studies are good in exploring, collecting and analyzing data of contemporary phenomena (Yin, 2009), the case study method is chosen as the research method for answering the second research question.

A case study research as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009, p. 18). Case studies can be an in-depth longitudinal study of a single case, but could also be a multiple case study. In case studies, it is critical to be as clear as possible about the boundaries of the phenomenon, in this case the abatement options. Therefore, the design of a case study is important. The way that cases are scoped, the unit of analysis selected, the data sources inquired, and the data collection chosen, among others are all relevant for the design of the boundaries of a case study. As abatement options can be quite different, the question is relevant because the Y-factor may not be applicable to all types of CO_2 abatement options.

By constructing case studies of abatement options, and applying the Y-factor in this process, insights can be retrieved of the applicability of the Y-factor. For example, when the same case study design face difficulties constructing the abatement option case, the applicability of the Y-factor may decrease and other research methods may be more suitable for testing the applicability of the Y-factor.

RQ3: How can CO_2 abatement options be compared by means of the Y-factor?

In answering research question two, six case studies have been constructed. This research question relates to how the data from the six case studies can be compared. Researching the abatement options one by one is interesting, but researching them side by side may be more interesting. As the Y-factor is used as an assessment tool, comparing the case studies should yield more insights. However, the way to compare could make all the difference. For this questions, several exercises are carried out to explore how the abatement options can be compared with.

Using the transition based conceptualization of the Y-factor of research question one, and the empirical data collected in research question two, the abatement options may be compared. Comparing abatement options may be perceived as comparing apples to oranges. How one compares them depends on their point of view, or in other words their perspective. For example, it could depend on a healthy point of view, (e.g. which one has more nutrients?), a situational context point of view (which one is better for on the go?), or perhaps from an economy point of view (e.g. which one has higher foreign direct investments?). In this thesis, the abatement options have been introduced in the perspective of the CO_2 climate transition. How do the abatement options compare from a transition point of view? What transition elements can be found in the six case studies? While case studies have limitations regarding generalization, it is still interesting as comparing in-depth insights could be relevant for the Y-factor as an evaluation method for abatement options.

With these three research questions, the aim is to contribute to the understanding of the Y-factor by means of an explorative case study from a transition perspective using empirical data.

1.6 The scientific relevance

The literature of the Marginal Abatement Cost Curve (MACC) is quite small. In a search in Scopus, using the keywords “Marginal Abatement Cost Curve” resulted in 227 scientific papers, at July 5th 2018. Relevant literature focuses on complementing and improving on the MACC from different research perspective, such as from an economic perspective. This thesis adds a system thinking perspective to the MACC with underpinnings from transition literature. The Y-factor is used as a device for a different non-economic perspective for the MACC. This thesis on Y-factor contributes to the body of knowledge of MACC by contributing empirical data and by testing it with a selection of transition literature. Two academic search platforms were used to scan the literature for MACC, Google Scholar and Scopus. In appendix B, a more detailed description of the search procedure can be found.

1.7 The CoSEM perspective

The Complex Systems Engineering and Management (CoSEM) perspective is one of the three main perspective at the faculty of Technology, Policy and Management. This thesis needs to meet the criteria of the CoSEM curriculum. The first requirement is that the work to have to inhibit clear design or engineering components. The design also has to have clear technology components. In CoSEM, process management and system engineering approaches are used. Complex issues are dealt with in a systemic and creative way and tools and techniques are used to assess impact in organizations. Last, but not least, the subject need to cover values from both the public and private domains. First, the thesis meets the first criteria by aiming to underpin and test an evaluation tool with the vision to design a better evaluation tool. Second, the design is geared towards a design fit with six technology domains, the six abatement options in this thesis. Third, the work is put into the wider process of decision making. Real life complexities are recognized and dealt with. The systems engineering approach is used, and argued for in the second methodology chapter. Fourth, this thesis aims to be systematic and creative. For this aim, this paragraph aims to illustrate the systematic approach partially by following the assessment criteria of the curriculum in a structured way, while trying to apply the principle of “show, don’t tell” at the same time. The purpose of the Y-factor is to better design a tool for organizations. Tools such as actor analysis and system analysis, and interview techniques are used for this purpose. Lastly, the multiple perspectives are used in this thesis, this is especially apparent in collecting data for the interviews, actors from different fields are specifically chosen for. With this last statement, a good fit with the CoSEM perspective is argued for.

1.8 The thesis outline

To outline the thesis, the report is structured as follows. In this first chapter, the challenge of abating CO_2, the role of the MACC and the complementary role of the Y-factor are introduced. The second chapter aims to presents the methodology of the thesis. In this chapter the transition research perspective is discussed that conceptualizes the Y-factor. Case studies are constructed by gathering empirical evidence in a structured way. An important part of the interview design is how the Y-factor could relate to theories, and chapter two ends with a literature review of transition and transition management theories for the Y-factor. Chapter three will present the case studies by presenting the case descriptions, analyses, and a concluding narrative. In this chapter, the applicability of the Y-factor on a variety of abatement options are assessed. Chapter four compares the six single case studies of abatement options that were presented in chapter three. Chapter four presents several comparisons to answer the question of how the Y-factor can help in comparing the abatement options. Lastly, chapter five is the conclusion and discussion chapter. The results, methodology, limitations and similar research will be discussed.

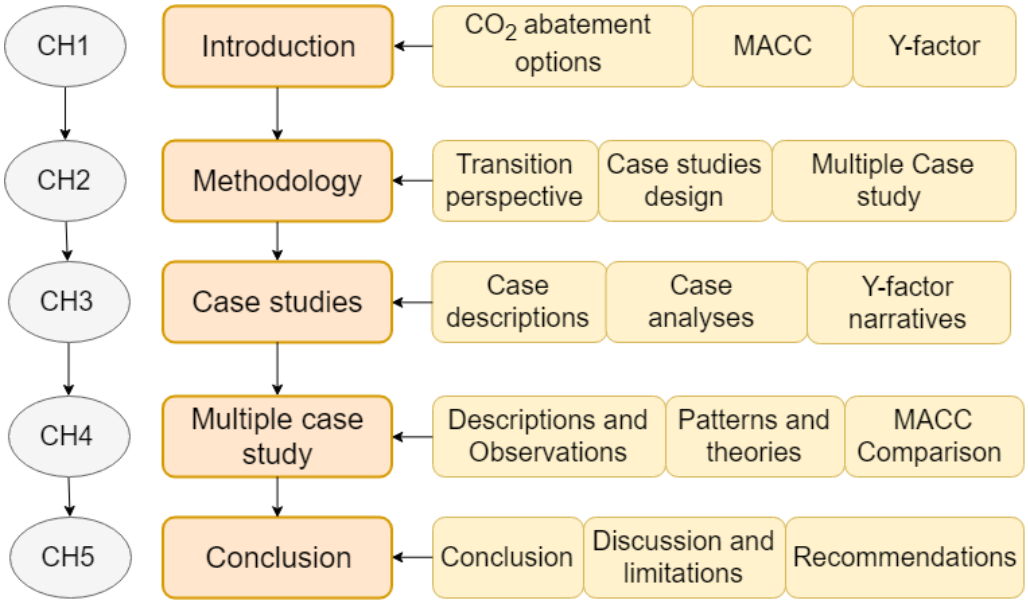

Figure 3 – Research chapter outline

2. Research Methodology

"If you have only four fingers on one hand, that's not a problem, that is a situation."
Kingdon, 1984

"People solve problems in four steps: intelligence, design, choice and implementation."
Herbert Simon, 1991

"Once you have a rigid way of thinking in your head, sometimes you can't change that even if you want to"
Destin Sandin, 2015

In chapter one, three research questions are formulated that ask for building up theories and empirical evidence for the objective of contributing to the Y-factor. In this chapter, the how-question for these two tasks is discussed. In section 2.1, the systems research perspective is introduced. In section 2.2 the case study as a research method will be discussed, along with its rationale and its case study design. Then in 2.3, the system is conceptualized, The interview design is also discussed. In section 2.3, the Y-factor as a crucial tool in the case study design is presented, and the transition literature is .

2.1 A systems perspective on abatement options policies

The situation after the Paris Climate Agreement can be perceived in various ways. In chapter one, the focus is set on the CO_2 abatement options. The assumption is that abatement options will contribute to the climate agreement and thereby the climate as whole. Climate experts and policy makers are referring to a "pathway to a low carbon economy" (Naucler & Enkvist, 2009), or "climate actions for decarbonizing the economy" (EC, 2017). If one would only focus on these two statements, it seems that the climate and the economy are equally important and that there is a need to more move from a high carbon economy to a low or zero carbon economy.

One way to look at the climate is from a system's perspective. A system is made up of subsystems and these subsystems interact with each other. A system may be a technical system, such as a bridge or a gas pipeline network. In such technical systems, the actions and interactions of the subsystems are subjected to the law of nature, albeit the law of physics, the bridge, or the second law of thermodynamics, the gas pipeline network. A system may also be a social system. The subsystems refer to the people and their organizations, and they are also subjected to rules, but to social rules. Sometimes a system can be perceived with both social and technical subsystem. In such a system, the interactions could be the social

rush hour system exerting its daily pressure on the bridge subsystem. Another example would be the alignment of the gas production systems with that of the households systems and their use of gas.

In this thesis, one can say that the socio-technical systems perspective is adopted, because the assumption is that abatement options are far from just technological artefacts, they also include social artefacts. Abatement options are sometimes about creating new infrastructures (wind energy as new components to the energy grid, biofuel, solar PV for housing, etc.), and other technologies. These infrastructures and technologies are more than just a collection of technical components. They are used and shaped made by individuals, companies and governments. Overarching rules, agreements and institutions exists in how people use, take and pay for them. With institutions, I refer to "legislation, regulation, standards, and market places" alike, and they may "emerges on top of the technological infrastructures and determines and facilitates the transfer of goods and services" (Chappin, 2011, p. 3). Simplify reality.

The Climate as a system in transition

From a system's perspective, the climate may be viewed as a system. The climate system would be made of various CO_2 producing and consuming systems. Such CO_2 systems may represent some part of our actual societal system in reality, for example a coal plant. The coal plant would then interact with other parts of the climate system through its CO_2 output. Removing or substituting the coal plant in the CO_2 production system, would result in a lower output of CO_2 and in turn result in a lower CO_2 balance in the atmospheric system. There is also a CO_2 consumption system. This could be the crops of agricultural sector absorbing some portion of the CO_2. Other CO_2 capturing or absorptions system may be relevant too, this is true for other CO_2 emitting systems. The notion of the diagram in Figure 4 is not to discard any other CO_2 production of consumption system, nor to represent that the interactions by the arrows are finite or absolute. The notion of diagram is to illustrate the climate from a systems perspective. The diagram may be extended further with many complicated interactions and subsystems, such as feedback loops, and other 2nd or 3rd order subsystems. For now, the exact specifications of the climate system, and it's the subsystems and interactions, are not known. The exact interactions or other rules at play, natural or social, are also not known. For now, the aim is to perceive the transition movement from a high carbon economy to a low carbon economy in this perspective.

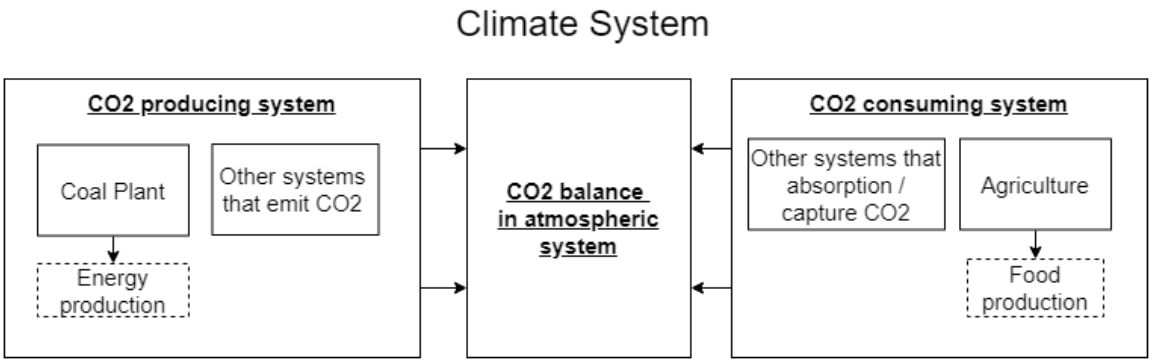

Figure 4 – The Climate as a system of CO_2 producing and consuming system

Assuming abatement options as subsystems for the climate system in transition

In the systems perspective, it can be said that a model for the transition to a lower CO_2 state is missing. The assumption is that abatement options have the means to do so in some way intrinsically. A transition in colloquial language is defined as "a passage from one state to another" or "a movement from one form to another" (Merriam-Webster, 2018). These two definitions fit the problem of the discussed climate system. The passage or movement is driven by the abatement options. Abatement options are seen as crucial parts of the transition to a

lower CO_2 state, then each abatement option could be seen as a subsystem of the wider climate system. From a systems engineering perspective, abatement options as components or as drivers, can then be managed and implemented.

If one or more subsystems show a change to a lower state, this may be called a subsystem transition. By extension and given a linear relation, the observed climate system as a whole may be assumed to be in transition too. From a systems perspective, transition occur from the many interactions of the subsystems, the desired final state of the system, a lower CO2, may or may not emerge from the interactions of the subsystems nor the design solution. However, if technology experts and policy makers create a transitional movement for the climate system towards a low carbon economy, a useful starting point of the policy design would be to study the dynamics of the subsystems and understand which mechanism from within the subsystem can be influenced and which ones cannot. It is quite possible that some subsystems cannot be influenced at all, or that some can be easily influenced on the contrary. Using the systems perspective as a scoping technique for establishing this conceptual notion of the relationship between the climate system and the abatement options as subsystems may then be useful for managing and implementing the climate system transition to a lower state.

Adopting the systems perspective allows the analysts to take a snapshot of the current climate situation and focus on individual abatement options. This perspective allows us to break down the complex and wider decision making process that characterizes climate policies. However, the systems perspective has downsides. For example, the perspective is necessarily incomplete, a snapshot only captures the situation inside a frame, and at a certain time. More about the limitations of the systems perspective can be found in the Discussion in chapter 5. Regardless of the limitations, the decision is made to perceive the abatement options from this perspective. One of the arguments is that to study all considerations that are relevant (e.g. outside the frame of the snapshot) may be “impractical in terms of time, money and human resources” (Enserink et al., 2009, p.46).

2.2 Case studies as a research method

Rationale case study

In chapter one, the thesis proposed to gather empirical data of actual and real life abatement options. The aim is to explore the CO_2 abatement options, and the aim is to do this qualitatively, because the expectation is that the observation would yield mostly non-numerical data. The aim is to also keep the number of cases low, so the cases may be studied on a more in-depth level. The focus is to study the abatement options on a more national and sector level, and thus stray away from the global perspective. However, case studies are hard to design. For example, in comparison to experiments, researchers lack the ability to control the environment and define the scope of the case. In response to this, the systems perspective can help. Abatement options can be seen as subsystems, and as such can be measured. From this perspective the climate system is relatively easier to understand. Researching the embedded units of one subsystem at a time, is relatively more easy than trying to understand the entire transition of the climate system at once.

Under these conditions of the assumed climate system, choosing case studies as the research method for the thesis is argued for, the conditions for conducting case studies are met. It is important to note that case studies have their own limitations. In case study literature (Yin, 2009; Swanborn, 2010), they are critiqued for their low external validity. Moreover, the cases could be situational dependent, and could be subjected to researcher biased. Case studies are also less suitable for theory seeking studies, unlike methods such as surveys and grounded theory. Qualitative data for case studies is also characterized by “interpretivism” as opposed to “positivism”. In short, these two are methodological and philosophical orientations, and have their own set of ontological and epistemological assumptions in the context of how knowledge is created (Papachroni & Lochrie, 2015). For researching the Y-factor, the aim to understand the underlying processes of the abatement options as a phenomenon as experienced by the practitioners, experts and policy makers themselves. Studying a phenomenon implies that is not yet quite clear what the spatial and temporal boundaries are

of the cases (Swanborn, 2010). This thesis acknowledge that the abatement options as cases are complex phenomena in an open social system, and therefore do not want to isolate the phenomenon from its natural surroundings and context. The systems perspective, which has the goal to reduce the complexity of the phenomena, is only an analytical approach to make the research process more manageable.

Type of case study
Several types of case studies exist (Yin, 2009). For example, single or multiple case studies. On the basis of our problem definition and research objective, multiple case studies are preferred, as the aim is to study several abatement options to understand the Y-factor more. Case studies may also be exploratory or explanatory. In this thesis, exploring the underlying assumptions of the feasibility of abatement options is the focus. The Y-factor may prove useful in identifying and finding such assumptions, An analogy discussed in Swanborn (2010) is found useful in the difference between a single and a multiple case study: “There are two ways to learn how to build a house. One might study the construction of many houses, perhaps a large subdivision or even hundreds of thousands of houses. Or one might study the construction of one particular house (Gerring 2007)”. The former is a multiple case study, and the latter is a single case study. Insights retrieved from the two approaches are different.

2.2.1 Case study design

Case studies can be designed in a few ways. The most important design variables of a case study are: the selection of cases, unit of analysis, the data sources, and the data collection (Yin, 2009; Swanborn, 2010).

For the **selection of cases**, the aim is to cover the whole spectrum of abatement options. Many types of abatement options exist. Abatement options are usually grouped into sectors or domain, as can be seen from table 2. However, different reports, make use of different definitions of sectors. It is unclear whether the same abatement options would be different under a different categorical sector name. To ensure variety, a selection one abatement option is made for each sector. Given the examples from the four reports, a selection of seven cases is made initially. These are: 1. Heavy Industry, 2. the Built Environment, 3. Mobility, 4. Energy Production, 5. Forestry, 6. Agriculture, and 7. Waste. In the Dutch Regeerakkoord, there are marked as five sectors. Due to practical reasons, the availability of cases in the Dutch Regeerakkoord is the decisive criterion. The Dutch sector of “land use and agriculture” is split among each other, resulting in the extra sector. The “waste” option in the Dutch Regeerakkoord is also split from the energy domain, and perceived as a separate sector. Due to time constraints in finding the appropriate interviewees, eventually, the sector “Mobility” is discarded. This result in a final selection of 6 abatement options in six different sectors. In analyzing the abatement options further, the decision is made to only focus on the details, keywords and references that the Dutch Regeerakkoord would provide.

Table 2 – CO_2 abatement options per sector

Publisher	**McKinsey (2009)**	**UNFCCC (2015)**	**Ecorys (2016)**	**Regeerakkoord (2017)**
Geographical focus	Global	EU	NL	NL
Classification Sectors	10	5	4	5

Another key design variable in a case study design is the **unit of analysis**. The unit of analysis may focus on a range of issues, this can be policies, a process or organizational change (Adams, 2010). The unit of analysis should not stray too far from the research questions.

Abatement options similar to that of the MAC curve are looked for. However, it is unclear what the abatement options are exactly in the MACC. For example in the McKinsey (2009) report, the abatement option “low penetration wind” assumes a certain the regional market volume growth, wind energy natural potential, and an average capex of €1300 per kW. Another example, the abatement option “2nd generation biofuels” is described as “modeled as lignocellulosic ethanol with 25 gCO_2e per MJ”, and with a price of “$1.38 per gallon”. These description are based on assumptions of in a certain context, perhaps from a specific economic and policy landscape, and on the basis of a series of projects. It is not known what the abatement options are specifically. Therefore the scope is set on the sixteen abatement options in the Dutch Regeerakkoord (in Dutch: “maatregelen”). On the basis of the details further provided in the Regeerakkoord, the unit of analysis of each case is set on details from a project level, as seen from Table 3.

Table 3 – Selected cases and their unit of analysis

Sector / Domain	**The options (translated)**	**Unit of Analysis**	**Case study (code) name**
Heavy Industry	Carbon capture	Focus on the project of the consortium ‘Smart CO_2 Grid’ by ‘Bloc’ for carbon capture and utilization (CCU)	1. CCU
Built En-vironment	Heat networks and heat pumps	Focus on projects for heat pumps installations of corporate housing.	2. Housing
Energy Production	Extra Wind at Sea	Focus on one of the wind parks project at the North Sea	3. Wind
Forestry	Smart land use	Focus on the afforestation project by the consortium of “Actieplan Bos en Hout”	4. Forest
Agriculture	‘Kas als energiebron’	Focus on biogas projects with fermentation installations on farms.	5. Green Gas
Waste	Carbon capture	Focus on carbon capture installations at waste incineration plants. in Dutch: afvalverbrandingsinstallatie (AVI)	6. Waste

In this thesis, domain and sector are used interchangeably. While both terms could refer to a geographic area or a zone, in this thesis domain is used more as a group of related topics and themes, such as energy production, or housing. A sector would focus more on the economic entities, such as a group of agriculture or construction companies and organizations, or a group of related industries, such as the drinking water sector or waste sector. In this situation, the difference in small. Until more information about the context is given, referring to the housing sector or housing domain would equally makes sense.

On the basis of the four reports regarding abatement options, and the details in the recent Dutch CO_2 agenda, six case studies are now defined for our empirical research and displayed in a diagram in figure 5.

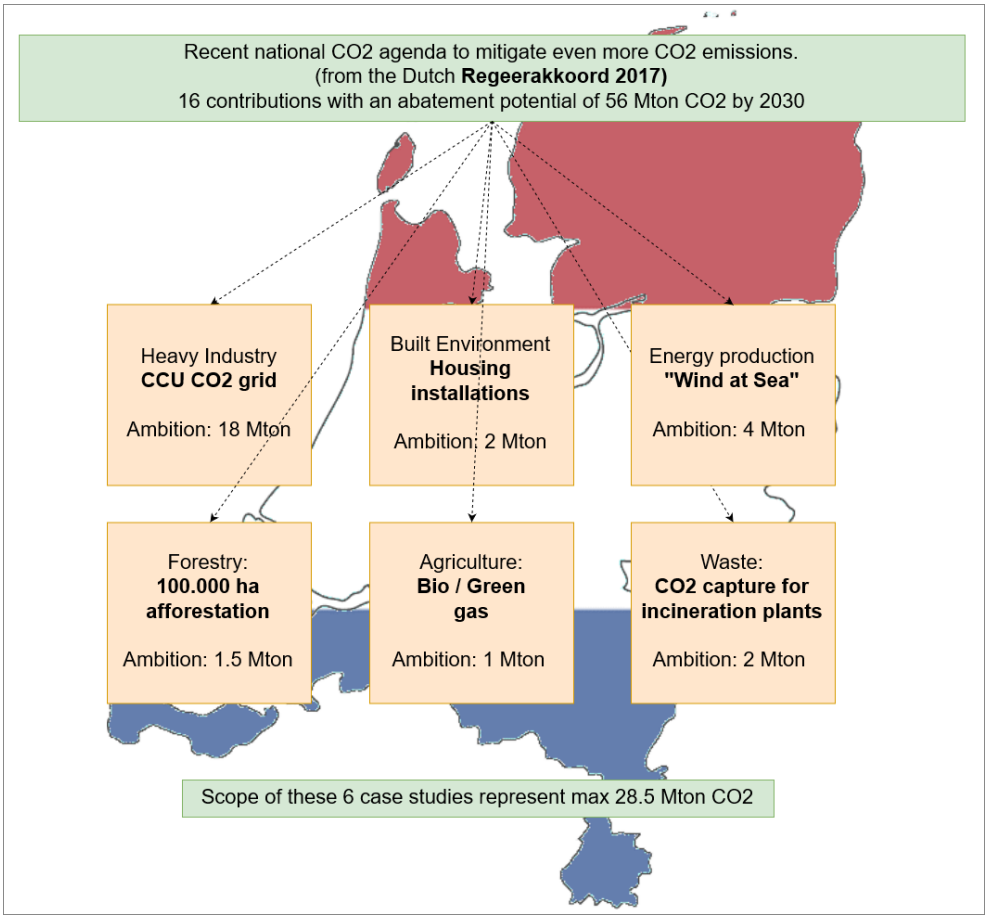

Figure 5 – Multiple case studies for assessing the climate transition

The last two important case study design variable are related to each other. They are the data sources and the data collection.

Data sources can be roughly divided into primary data sources and secondary data sources. The data derived first-hand by the researchers are observations, surveys, interviews and focus groups. Secondary data sources are sources that pre-existed before and gathered by other researchers. Example are data records, library searches, articles and reports.

In this thesis, mainly primary data sources are included. The interviews are the main form of data for the case studies. Some secondary sources were used to prepare the cases. Several ways exists to gather primary data. Questionnaires or surveys, interview and focus groups are discussed. Questionnaires relies on somewhat large samples, and tends to limit the scope and knowledge obtained. Usually, questionnaires are used for claiming some sort of relationships between the questions or factors. For this thesis, no relationships are claimed between the Y-factors. Focus groups, requires a pool of individuals or experts available for a specific cause. Gathering and facilitating such groups would also be too impractical given the explorative nature of this thesis. Given the variety of the abatement options, this would be too time extensive. The abatement options are characterizes as dynamic and have large time spans, and therefore making observations is not a practical option given the scope of the thesis.

For sufficient and more nuance sources, multiple perspectives should gathered from interviewees. A useful method for multiple perspective could be derived from the Triple Helix perspectives. The Triple Helix (Etzkowitz and Leydesdorff, 2000) makes the notion that innovations occur when academia, government and industries are involved. From a transition perspective, innovation may drive transitions. Hekkert et al. (2007) connects innovations systems with transition (Chappin, 2011, p.34). The argument is that the development of knowledge is important, but so is the knowledge diffusion. The knowledge has to get to the

market. Such knowledge is valuable, but takes it work and human resources to gather, dissipate and made relevant for the appropriate user. The Triple Helix perspective prescribes that such knowledge should come from at least three perspectives. Using the three perspective to create variety in our interviewee pool is a way to get a more nuanced and unbiased perspective on each project or program. For the governmental perspective , in transition literature, there seems to be “little consensus” about the role of the government (p.39). In transition, often a small role is given, but it is acknowledged that governments do have the policy instruments to block or trigger transitions. For the Dutch cases, the assumption is made that the government has a significant role in transition. The rationale for this is the assumptions that the Netherlands has strong international relationship and strong national (governmental) agreements. This can be seen by the Dutch cabinet reference to the Paris Climate Agreement, and the variety of measures to facilitate transitions. In the past, the cabinet has drafted an own national energy agreement in regard to renewables and also drafted an energy law. In the past cabinets agreement, a national climate law is suggested (PBL, 2017). From this it does seem like the government has a role in transition. In transition literature, groups of engineers, firms, societal groups and more are mentioned (Chappin, 2011, p.20). This corresponds partially with the notions of the Triple Helix. However, the enormous differences in perspectives found in transition theory should be acknowledged, but for practicalities, the total type of interviewees in our case studies should be limited. Under these assumptions, the Triple Helix seems useful.

The Triple Helix notion will be implemented in this thesis as the SKG perspectives (Stakeholder, Knowledge and Governments) for further analytical purposes. The definition are the following: Stakeholders are organizations or companies with an actual asset at stake or they are represented by an organization whose member do have an actual stake in the abatement option. Knowledge organizations may come from academia, but may also be seen as research institutes, or technology consultants as representing the Knowledge perspective. For the perspective of Government, the respondents must be policy officers from a ministry, an agency, municipality or other types of government.

For the **data collection**, the main technique used is sometimes referred to as the semi-structured interviews or in-depth interviews (Adam, 2010). A short analysis of the semi-structured interviews as a research method can be found in appendix C. Three works (Sharyer & Walsh, 2007; Raworth et al., 2012; Adams, 2010) has been reviewed in their methodological steps and their interviewing context. In short, several techniques were discussed for finding the right data, such as “snowballing” and identifying “key informants”, but also ask “probing questions”. An interview guide or template is said to be imperative, and should be created to stay on course with the research questions, but also as a fallback sheet when actually conducting the interview. In this interview guide, the questions can be open-ended but also closed-ended. The interviewer should have neutral and unbiased questions, and should aim for first questions to be more open and general, but have another set of follow-up questions with more specifics. Questions should be checked before on its possible answers on known websites or other sources. If the questions are found to be too descriptive, reformulate and check whether they still comply to answering the thesis. Different groups might also need a tailored interview guide.

2.2.2 The interview guide

In conducting semi-structured interviews takes a good amount of preparation work and the careful design of the interviews. Figure 6 summarizes and illustrates the preparations in a process diagram. The problem context, with the explicit notions of the six cases, and the variations in interviewees through the Triple Helix perspectives, is seen as the building block for providing the scope of the interview guide. The introduction will most likely need this problem context, but for the interview guide, the written information should be limited to the case that the interviewee belongs to. The review of the semi-structured interviews methods has given us requirements to design the interview guide, but also in selecting and inviting

interviewees, more on this in the next paragraph. Last, but not least, the interview guide will consists of the 13 factors of the Y-factor. The factors will be shaped as questions. See appendix D, for an example of the interview guide and the Y-factor assessment framework. Using these notions as building blocks, the interview guide is built.

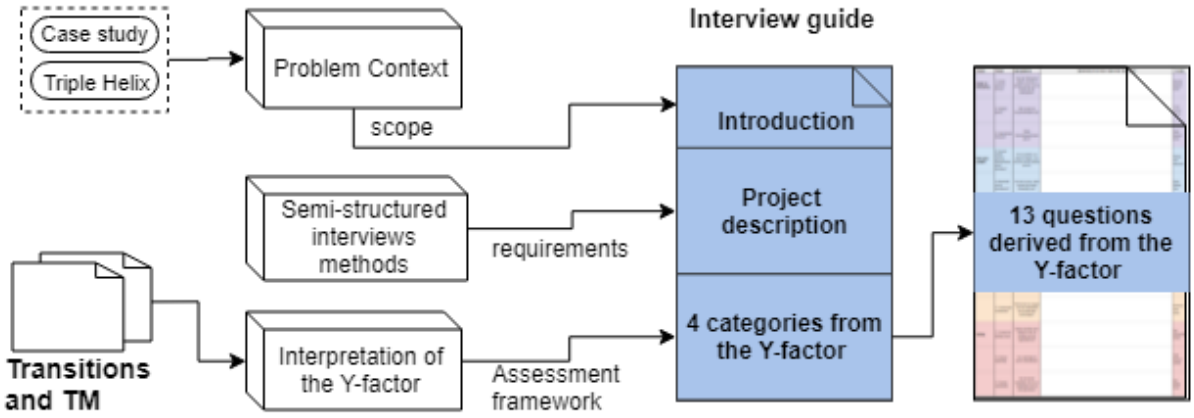

Figure 6 – Design of the interviews

Selection of actual interviewees and personal introduction

In this thesis, 6 sectors and the three SKG perspectives are used as a framework for the selection of interviewees. In searching for the actual contact details, first a desktop internet search is carried out by using the keywords and projects names in the descriptions of the Dutch Regeerakkoord 2017-2021. Then authors of case relevant reports and white papers from the government or industries are seen as potential interviewees. A long list was created, which turned into a short list after consulting with the practical availability of the interviewees.

The interview guide should be to a certain degree personalized towards the interviewee. Before the actual invitation and the question of availability, the interviewees are explored on the social media platforms, such as Linkedin. Linkedin was used the most, as it could provide good information about the interviewees. This step before the actual invitation is important, as the interviewee should be an expert or a "key informant". The labelling of someone to be a "key" informant is part of an persona analysis, in which the notion of “key” can be assigned to if that someone is knowledgeable about the research topic through something that he does daily or weekly; through his work, volunteering activities or other activities (Adams, 2010). To ensure some level of being knowledgeable or involved in the actual abatement options, the interviewees are therefore scanned in their persona. In showing good preparation efforts, and gain develop trust in spirit of good interview principles (Adams, 2010), the introduction of interviews should contain a check of the involvement of the interviewees, the specific report or place I have found their contact information, and why I think they are my key informant and thus the right person for my research. In this introduction, I should also mention that I make use of the audio recordings. Emails were the primarily medium for inviting the interviewees. In appendix E, an example or the template for the email invitation can be found, as well as some anonymized background information of the interviewees.

The project description in the interview guide

Every case should have a project of the **scope**. The scope of the project explains the problem of the project, the success criteria, the project boundaries and the costs, adapted from Project Management Knowledge Areas (Larson & Gray, 2015). The **time** of the project and its milestones are important aspects of projects. It is also important to know which parties or stakeholders are **involved** in preparing and implementing the project. For semi-structured interviews, it is important to know recent information of the project and to know about some public information of the project, insights into the **media coverage** would help in doing semi-

structured interviews (Handbook of SSI). Getting to know the recent sentiments around a project will help in putting the questions in the right context.

The Y-factor as an assessment framework: the 13 factors and questions
In the interviews, the Y-factor is used as an assessment framework. Semi-structured interviews requires a fixed set of interviews question, but also a set of open questions. The assessment framework should be as unambiguous as possible. The 13 subfactors of the Y-factor are transformed into neutral questions as much as possible. The follow-up questions, also known as probing questions, are composed as well. In semi-structured interviews, it is more important to listen than to ask questions. A good amount of knowledge of the 13 factors should be established. In section 2.5, the Y-factor is explored using transition literature. An example of the assessment framework can be found in appendix C.

2.3 Conceptualizing of the Climate System in regards to the Y-factor

From a systems perspective of the climate, one may look at the interventions of this climate system from a global and European perspective. In Figure 7, the policy and political processes over time are depicted at a high United Nation level and at the European Union level. The INDCs, introduced for the Conference of Parties (COP21) in the Paris Climate Agreement in 2015, can be seen as commitment devices, but also monitoring documents for “mitigation efforts”. Mitigation is to be seen as different than that of “adaptation effort”. In short, adaptation is about becoming adjusted to the effects of climate change, and mitigation is about reducing the greenhouse gasses causing the climate change. From the perspective of the Paris Agreement of COP21 (Conference of Parties), the previously known ETS system (Emission Trading Scheme), while mainly focusing on reducing CO2, should also be interpreted separately from the mitigation efforts, as the “mitigation efforts” terminology in the Paris Agreement aims to capture everything outside the ETS system. In this thesis, the focus is only on the mitigation efforts in the INDCs documents. In Europe, the Member States of the EU have formed a bloc to jointly establish and work on the INDCs. Over time, it is assumed that the commitments set forth in the INDCs and its continuous monitoring over time with other parties and members states, will provide enough inputs for a legal framework for all parties to agree. In the meantime, parties will continue to work and improve on their INDCs, and the first country to turn their INDCs into NDCs (Nationally Determined Contributions, without “Intended”) has yet to come.

Continuing from this wider view of the policy processes, INDCs are to be evaluated and improvement over time through national and international dialogues. To support these dialogues, methods such as the MAC curve are used. In this thesis the focus is on testing the applicability and usefulness of the complementary Y-factor method. As seen in figure 7, several green oval shapes are drawn on the level of Member States. These green ovals represent abatement options and each have their own CO_2 potential. The yellow rectangle represents the background societal processes. Assuming that the feasibility of the abatement options depends on a variety of known and unknown societal processes, and assuming that the Y-factor has useful notions on each of the abatement options, the abatement options may or may not emerge and transition into a new technology, an industrial revolution, or an energy production transition. The red dots represents the possible factors, stickiness or embeddedness from the subsystems that is stemming from the background societal processes (only depicted in the figure as a large yellow rectangle). In this diagram, it is unclear what the relevance and weights (or size) are for these red dots for every green oval abatement options. The goal of this thesis, to contribute to the Y-factor for abatement options, is conceptualized in the wider decision making process as such.

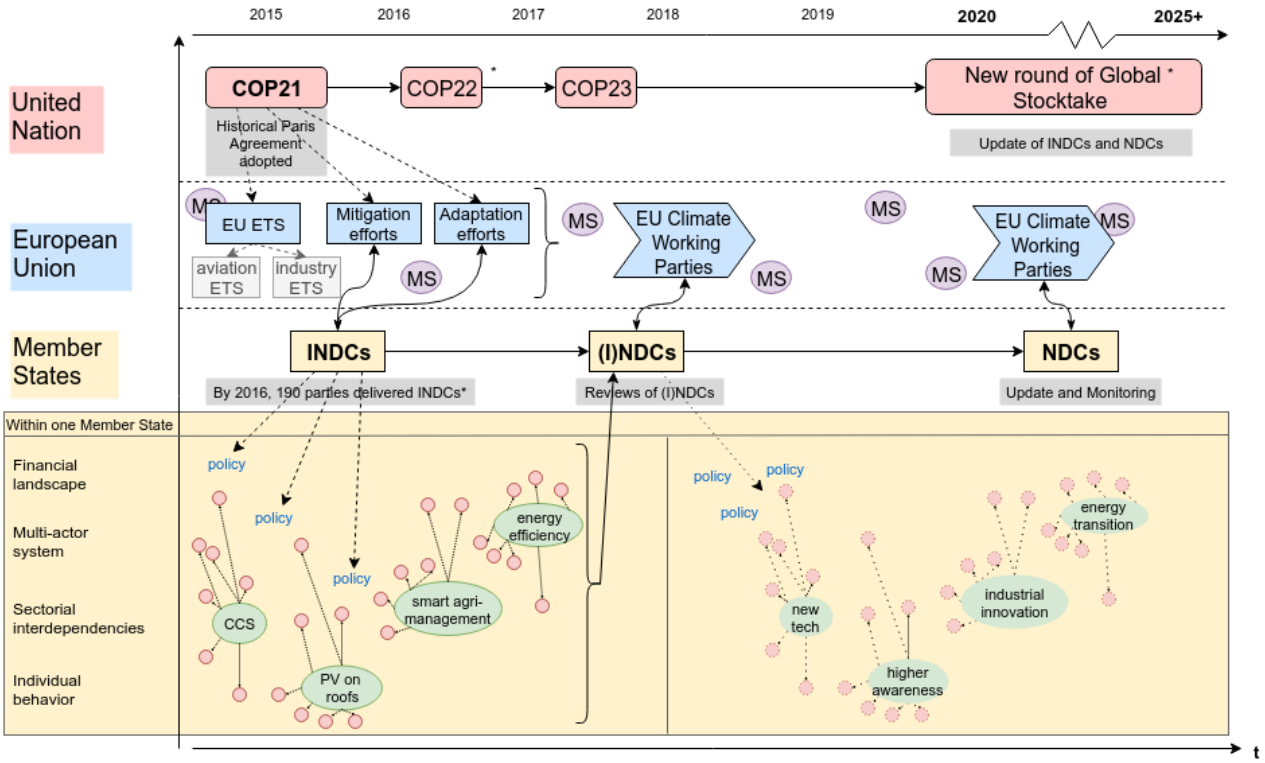

Figure 7 – The Y-factor from a wider climate transition context

2.4 Transition theory and Transition Management theory

Transitions are common terms in the world of STEM (science technology engineering and mathematics) studies. In physics, atomic transitions are when electrons jump from one energy level to another (Wiese et al., 1966). In molecular biology, a transition could refer to the mutation of pyrimidines (T to C or vice versa) or purines (A to G or vice versa) (Tamura et al., 1993). When talking about phase transition, it could be about going from one state of matter to another, such as the change between solid and liquid, but also gas and plasma. In this thesis, the transitioning of an economy or a society is interesting. Classic and popular examples of transitions may include the transition from steam to electric engines, from surface water to piped water, from horse-drawn carriages to cars, from analogue communication to digital and modern communications technologies (Smith et al., 2010). However, transition economy in the context of transforming "a centrally planned economy into a market economy" (Alexander & Skapska., 2003) may be a different level of analysis. According to the IMF (2000), four main indicators for transition economy are "liberalization, macroeconomic stabilization, restructuring and privation, and legal and institutional reforms". In this thesis, transitions from a systems perspective, as proposed in 2.1 is the focus of this thesis. The following table of relevant definitions for a system in transition are used. The literature review procedure for this section can be found in appendix B.

Table 4 – Definitions of Transitions

Definition	Author(s)
"Transitions are transformation processes in which society changes in a fundamental way over a generation or more."	Rotmans et al. 2001
The idea of transition is "a substantial change and movement from one state to another"	Shove and Walker. 2007
"Transitions are the outcome of the interactions between actors on one level and interactions between levels"	Kemp et al. 2007

Transitions are a “system level of change”, whereas “technical change alone is not sufficient, changes in the social dimension – such as user practices, regulation, and industrial networks - are inevitable.”	Hekkert et al. 2007
Transitions are processes of structural change in societal (sub) systems such as energy supply, housing, mobility, agriculture, health care, and so on (Geels 2002a; Rotmans et al. 2000).	Loorbach. 2010

In Chappin (2011), the energy transition has been viewed as a transition from a systems perspective, several key concepts are mentioned to be relevant, such as multiple phases, multiple level, and multiple domains.

Multiple phases
Transitions are characterized by many notions of “change” (Chappin, 2011). Chappin discusses, on the basis of a literature review, that this change can have different sizes, speed, timing, and different types of change, such as structural, irreversible, fundamental change and more (p. 16). In the notion of change, phases are important. Transitions may have multiple phases (Loorbach & Rotmans, 2006):

1. The Pre-development phase
2. Take-off phase
3. The Acceleration phase
4. The Stabilization phase.

In the Pre-development phase, the transition is said to be relatively stable. There is little visible change, but a quite some experimentation at the individual level. Once the system starts changing, the Take-off phase has started. In this phase, “the process of change starts to build up” (Loorbach & Rotmans, 2006, p. 3). The Acceleration phase announces a major change. This is a structural change in a visible way. There is implementation of “socio-cultural, economic, ecological and institutional changes” (idem, p.4) The last phase is when the change slows down, and comes at a halt and become stable again.

Multi-Level Perspective: niche and regimes
Transitions can be described as going through three levels, from a multiple level perspective: the micro, meso and the macro level. In the Multi-Level Perspective (MLP) by Geels and Kemp (2000), the micro level describes the technological niches. Niches are active on the micro level, and in this level new technologies are invented and developed. These technologies may later become the norm and may breakthrough. The breakthrough is breaking from the niche level to the regime level. In MLP, innovations are explained by such breakthroughs. Niches have to mature and survive market conditions to be able to breakthrough. The regime level can be defined as

- A regime refers to the shared routines in a community of engineers guiding through R&D activities (Nelson and Winter, 1982)
- A socio-technical regime consists of “coordination within and alignment of the activities of engineers, firms, scientists, users, policy makers, societal groups” (Geels, 2004)
- Patterns of artefacts, institutions, rules and norms assembled and maintained to perform economic and social activities (Berkhout & Stirling, 2004)
- A regime might “strike back” (Loorbach & Rotmans, 2010)
- Parties who have influence and power and making an effort to stay in that position. Regimes protects themselves from a variations of niches (de Haan, 2017, p.30)

The many definitions of regimes indicate that regimes are not easily defined and that its boundaries are not trivial. The macro level refers to the Landscape Development level, this is a slow moving background force that may put both positive and negative pressure on the regime. These forces allow for innovations by creating windows of opportunities for new ideas and concepts. Through such windows of opportunities at the regime level, technologies at the niche level may breakthrough and establish a new element in the existing regime. This is sometimes called a regime shift, or this is sometimes described as the process of innovation (Geels and Kemp 2007)

Transition Management

In the situation, whereas there is a certain desire to contribute to a transition, and thereby "managing the transition", Transition Management (TM) has been seen as an often used and new approach (Loorbach, 2010; Loorbach & Rotmans, 2010). In the theories of TM, transition may be managed. However, management in this context should not be confused with management from an classical organizational perspective. Two types of TM can be defined: 1. Intra-organizational TM and 2. Inter-organizational TM (Chappin, 2011). The difference is that the first relates to processes within organizations, and the second relates to transition management at the level of a group or network of organizations, a whole sector. While the level of scale is different, a common notion is that for both management perspectives, it is important that difference departments (intra-organizational management) or organizations (inter-organizational management) should somehow be brought together, and come to a common sense of urgency of a situation and problem. Different disciplines (within an organization) or domains (within a network of organizations) should be involved. Generating and creating new knowledge by the different organizations, and thereby achieving a new collective understanding is important. Equally important is the knowledge diffusion and knowledge facilitation of this new understanding across the whole sector. From a government perspective, TM can be considered as a specific form of multi-level governance (Scharpf 1994, 1999; Hooghe and Marks 2001). Kemp et al. (2007) explains this governance approach "whereby state and non-state actors are brought together to co-produce and coordinate policies in an iterative and evolutionary manner on different policy levels." (p.5). Rotmans (2010) summarizes TM with the following characteristics:

1. Long-term thinking for shaping short-term policy
2. Thinking in multiple domains and different actors at different scale levels
3. A focus on a special learning philosophy (learning-by-doing and doing-by-learning)
4. Bring about both system innovation and system improvement
5. Keeping options open for a wide playing field.

In understanding these five characteristics, the reviewing of the definitions of transition in table 4 may be useful. In short, transitions are societal changes, it covers generations or more. The changes are substantial, and occur on multiple levels. Technical changes are mentioned, but also social changes, and may involve various industries. In the definitions of transition, all five characteristics makes sense. Transitions requires long term thinking, span multiple levels, and different disciplines and different organizations are needed. Learning among different disciplines and domains is needed. In transition, regimes are capable of creating a better system, a system improvement. They are commonly seen as small and incremental. In transition, system innovation may refers to niches breaking through regime level and change the regime in such a way that it is commonly seen as a system innovation.

Transition Management and the Transition Arena

In the Multiple Level Perspective, the regime level can be perceived as a much more organized, but complex social network. Within the context of transition management, a Transition Arena (TA) may be established. The TA refers to the virtual network that can be created to incorporate visionaries, innovators, frontrunners and champions (Loorbach, 2010). In short visionaries are people who have worked, experienced, studied and reflected upon

their time and their field of work. They have a vision for what's to come next, a feeling for what is important to think about and eventually act upon for the larger and greater good. They have reflected on their own field in such a way that they have developed the capacity of looking at the bigger picture. They have also gained traction over time in their field of work, but also in cross industry. People who have just entered the industry might even recognize these visionaries even if it's just by name. The visionaries represent a large proportion of their respected industry and may influence, shape or nudge certain resources, albeit human resources or capital resources. They don't have to have a direct influence, as transitions cannot be fully steered and governed, but do have an indirect influence. The TA may therefore be perceived as operating and managing from three levels, the strategic level, tactical and operational. They relate to the MLP levels. At the strategic level, the problem is structured, a future envisioned, and long terms goals are composed. At the tactical level, the agenda has to be built, negotiation has to be done, and networking. At the operational level, there are experiments, projects, innovations and other relevant implementations. The TA should only consists of 15-20 such individuals, and may enter the arena and leave the arena (Rotmans & Loorbach, 2009, p. 192). However, a core group of around 5 will form organically over time. In this arena, parties that do not have a stake in a particularly industry or policy should also be represented from time to time. Experts should also be invited to the arena. They are independent and bring knowledge and expertise to the arena, and it is assumed that such knowledge and expertise from their perspective will induce a better functioning transition arena, and keep every party sharp, and keep the transparency and the fairness of the process high for the public audiences of the arena. In short, transition arena are crucial, and should produce transition-visions, transition-coalitions and networks, and transition-experiments.

2.5 The Y-factor as an assessment framework for case studies

In this section, the transition and transition management theory are interpreted in the context of the Y-factor. The Y-factor with four grand categories (or themes) as why it is that abatement options do not perform in a way that the otherwise more economical counterpart (the MACC) would prescribe. This section explain per subfactor, from the research perspective of transitions theories, why the subfactor would matter or does not matter at all. The goal is to use this as an assessment framework for the proposed case study interviews.

Table 5 – The Y-factor as an assessment framework for case studies

Category	Subfactor	Definitions, what is the theory? (EN)
Cost and Finance	1. Investment cost required	From the perspective of transition, individual projects are often not the main focus. If projects are analyzed they will mostly be analyzed from a meso-level; referring to the business to business market, or the business to government market. Transition management (TM) focus on the managing of the whole sector. The market should be fair and there should be a level playing field. From the perspective of neoclassical economics, investment costs are costs that need to be made upfront before any value can created and subsequent revenues to be earned.
	2. Expected pay-back time at €0/ton	From the perspective of neoclassical economy, the investment costs may be earned back by looking at the "break-even point". The break-even point is a future point in time where the sum of all the revenues minus the sum of the all the operational costs meets the investment costs. In CO_2 related projects, often the CO_2 price per ton is an important indicator. The assumption is that the owners of the projects are paying CO_2 emission rights. These saved costs may then be added to the calculating the break-even point. So say that 1 Mton of CO_2 is reduced, and at a CO_2 price of is €10, then €10 million may be added to the break-

		even point calculation, resulting in a shorter payback time of the investment costs. However, if it's uncertain whether these CO_2 savings apply, or the CO_2 price itself is highly uncertain, it may be unwise to take that into account for the break-even calculation .
	3. Difficulty in financing investment	Financing is to be interpreted differently from just the capital and the operational costs or expenditures. Finance is about managing the monetary processes that comes along a business case, given naturally that this is positive. From a neoclassical economy perspective, a business case is the reasoning for a project or task that would justify the costs made for achieving a particular business goal. Often for investors this may boil down to whether a business goal set forth will generate or increase in value so much that it will justify the capex and the opex of that particularly project. So financing a business case may involve contracting costs, interests, the valuation of assets, a security deposit or collateral among others. As financing is a whole discipline in itself, the concepts may have been (inexcusably) oversimplified and misused. However, in the context of the Y-factor, the perception of the expert of the financing difficulties is still important.
Multi-actor systeem	5. Number of actors	In TM, the technological system is important, but also the social system. With actors all the individual actors that might be influenced are referred to. Actors may be involved directly or may some actions. However, the boundaries between directly and indirectly are blurry, are actors from 1st order networks taken into account, or also the 2nd? What is defines the 2nd order? In this question, the Y-factor wants to know whether it is in the few, thousands or millions. From a TM perspective, this question can be understood as the size of the social system. This may refer to the demographics. However, it is not about the whole population of a nations. It is not about how society have transitioned from the industrial age to the modern age. It is about the specific of the sector or the domain of the transition. (see the hierarchy of transitions). The metaphor of a helicopter view may be used to approach this question. To conclude, this is about how many people are involved in that (socio-technical) transition?
	4. Dependence on other actors	Are people and organizations able to do just their activities independently, or are they strongly dependent on other for doing that? From a transition perspective, actors operate in a network, groups, or communities. Actors on which many actors are dependent on can be seen as important actors. If there are many important actors, the "actor constellation" may look very large and complicated. However, while the actor constellation may look complicated, this does not mean it is complex. For example, the large actors in the field may be very organized and for a complicated task a complicated arrangement or organization is needed. This question may therefore be understood as to assess the dependency of the actors in this actor constellation, who are the importance actors and given the transition, is the dependency low or high?
	6.Types of actors involved incl. conflicts	Important actors have influence and power. Together this may be blocking power or a stimulating power. This depends on the attitude of that actor towards the transition. The attitude may depend on how actors perceive the impacts of the transition in relation to their interests and goals. If their interests is at stake, actors may have a negative attitude towards the transition. One may speak of stakeholders in this context, as the actors have a stake, and may act differently depending on their stake. Different types of stakeholders therefore exists, and stakeholders may form coalitions. If transitions can be perceived from a game theory perspective, there may be winners and losers. Unlike a game, where there is a start and end, real life situation are dynamic and continuous over time.

		Winning and losing should therefore be used with nuances. Winning or losing just mean that a certain player is slightly better off or slightly worse off. However, like a game, teams or coalitions may be formed as well. In TM, the **transition management arena** is used to denote the situation where actors form coalitions and create this virtual arena full of visionaries, frontrunners and supporters. Idea's and topics are fought over in this arena, and not the best, but the most fitting idea wins. Sometimes stakeholders may be "forgotten" too, and left out of this arena. This may happen to stakeholders that have little influence and power, independently of their stake. This may happen because the game has changed, and there is a window for players to leave and enter.
	7. Responsibility unclear	From a TM perspective, different roles for governments, companies and other actors are described. For TM, knowledge is what needs to go around. Knowledge need to move from one place to another to drive the desired transition. The execution of projects, but just as important the monitoring of the projects and evaluation of the projects are equally important. These roles should be clear, but should also stay clear over time. Sometimes these can span several years, and as one may see, the knowledge or the "lessons learned" ought to transcend companies and organizations to others in the sector or domain.
Physical Interdependencies	8. Physical embeddedness	In TM, the technical systems and subsystems are also important. The same social system with a different technological system may transition completely different. The technical system may be the geographical system, the (above or under the ground) infrastructures, the urban system and the environmental system among others. Here it is not about the developmental stages or mechanical structures of a particular technology system. In telecom for example, the network communication technology is embedded in many types of physical and technological systems. E.g. the "OSI reference model" is sometimes used to indicate the embeddedness in telecom. This subfactor is related to being embedded to other systems.
	9. Disturbs regular operation	Transitions may occur fast and abrupt. Sometimes it is like dancing on a needle, it can suddenly go very fast. A transition may have many projects, and actual projects are subjected to a series of implementation stages. This may take months or years, and in these stages, disturbance to other systems, such as the direct surroundings may occur. This may also be disturbing the daily lives of someone on the road, or on a boat. The main difference with the previous subfactor is the direction of influences. The embeddedness is about how other systems influence the case, and this subfactor is about how this case could influence the other systems in its environment.
	10. Technology uncertainty	Technology and its innovation is an important port of transitions. Technologies may still be in research & development, or about to be adopted and mass adopted. In transition knowledge is created and shared across the industry, just think of the early internal combustion engine technology, and how it became widespread and mainstream and used in cars up until now. Until some technology survives the harsh market conditions, and comes out of the niche level, the technology will be perceived as uncertain as opposed to being mass adopted in the market.
Behavior	11. Outside of thinking scope of actor	From a transition perspective, thinking outside the box is a necessary mechanisms within the niche-level. In the niche level, inventions take place, or new technologies emerge. This may not happen if people are operating within their own beliefs and a fixed set of "problem and solutions" for a too long period of time. Pressure from outside may create the necessary room for experts to think outside the box. One possible way of assessing this is through the element of

		constructive surprise. Asking their agreement or involvement with the recently published vision of the cabinets agreement, might give an indicator of some insights of the case's behavior. The theory is that when experts are pleasantly surprised, that people might reflect and think about their rooted beliefs and their previous set of problems and solutions, and result in another behavior.
	12. Frequency of opportunity	From a transition perspective, organizations have to be have the reflexive capabilities to act on opportunities. They need to be able to look outside the boundaries of their respective organizations. When people are not giving enough time or space, people do not receive 2nd or 3rd order learning effects For transitions it is important that the sector is characterized by, learning and by learning by doing. By asking normal business opportunities, not specifically related to CO_2 businesses, one may get insights into how frequent opportunities are taken advantages of. This question is different as being entrepreneurial doesn't necessary mean thinking outside the box.
	13. Requires change in behavior	In transitions, government changes, organizations changes, the whole regime changes. This imply that changes are imminent for the average joe as well. Such changes may be a change of "shared routines in a community of engineers" or a change of "mode of operation", a different way of working. Habits that are changing. For example, by changing the isolation of houses, people might not notice much of their behavior on a daily basis. The house stays warm longer. However, a commonly used examples with electric cars. In the transition towards a full electric car stock, end-users need to charge their car every one or two days. Fellow house members might also notice the extra installations, or have to rent a second car for long distance trips. These changes does not have be unpleasant, it just have to be somewhat significant.

2.6 Relation between the Y-factor and transition theory

In this chapter, the methodology of the thesis is discussed. The key research perspectives are elaborated in section 2.1, 2.2 and 2.3. In section 2.4 and 2.5 the key concepts and theories are discussed on the basis of a selection of the transition literature. The latter two sections give insights to how the Y-factor relates to the theories of transitions, this is the first research question.

To relate the Y-factor to the perspective of transition theory, an assumption is made. The assumption is that the subfactors are mutually exclusive and collectively exhaustive. This means that the assumption is made that the transition theory perspective adopted is able to cover the Y-factor framework in every of its 13 subfactors. No new subfactors are suggested from transition theory. The transition theory is only used to substantiate and explain the subfactors. Not in the least, because of adding new subfactors might bring along a whole set of (new) challenges, a whole new set of research questions. The Y-factor creates a convenient structure, and the Y-factor can be seen as verbal device to explore the level of complexity and the underlying models of the abatement options, nevertheless.

In exploring the Y-factor from the perspective of transition theory, one can say that the Y-factor does not completely relate with transition theory. This is discussed in using the four categories of the Y-factor in table 6. Nevertheless, the transition theory is useful in formulating some expectations in terms of the expected score of the Y-factor.

In formulating expectations of each of the 13 subfactors of the Y-factor from a transition perspective, one may start by the perception that abatement options may go through different transition-phases. In these phases, transitions may temporally behave differently and as a consequence, abatement options should be revisited and adjusted accordingly. Transitions may be difficult to control and manage, but through thoughtful shaping of the underlying

drivers, or the abatement options, transition goals may be reached. An important driver for abatement options may be the effective management of the Multi Actor (MA) complexity. In a complex network, a transition arena are created to facilitate and support visionaries and frontrunners in creating strategic visions, tactical coalitions and operational experimentation and innovations. From the perspective of the Y-factor, other important drivers of abatement options are through the management of interdependencies and behavior. From a transition perspective, transitions are fueled by the collective action of many individuals, but also by their capability and available tools. For example, the right infrastructures should be available and within reach. Moreover, transitions projects are fragile and is most likely to succeed in the most favorable conditions. Transitions are also characterized by many projects, and may be subjected to long stages of implementation, which could highly disturb other systems. Shaping the right influences will promote the right kind of collective action. And managing the dependencies from old systems and promoting a culture of knowledge, possibilities will appear and pathways towards transition will open. A dominant behavior of learning and taking business opportunities may help in gaining traction of transitions projects, and thereby driven transitions themselves. Such projects might be risky, but innovation requires niches taking chances and try to break through the regime. On the basis of this narrative and table 5, the following expectations of the Y-factor is formulated in table 6.

In formulating the expectations of the Y-factor from transition theory, one may argue that the some parts of the Y-factor is more relatable to the transition theory than others. For example the Cost & Finance category is the least relatable to the Y-factor. The most relatable one is the Multi Actor category. The Y-factor could be considered as a tool when (re-) visiting the abatement options. Depending on the abatement options, the gathered data may be used to identify the most urgent transition element for policy making. However, the Y-factor is not meant for creating transition elements. The Y-factor may also be the least suitable for assessing finance difficulties for abatement options, other tools or frameworks should be considered.

Table 6 – Expectation from and relation with transition theory

	Expectations from theory	**Relation with transition theory?**
Cost and Finance (C&F)	1. High investment costs 2. Long payback period 3. High difficulty financing	Few relation within transition theories. Transition is about a collection of projects, and the survival of the harsh market conditions, not single projects.
Multi Actor (MA)	4. Many people 5. Many dependencies among actors 6. Many types of actors 7. Slightly unclear roles	Quite relatable to the multiple levels and transition arena. There should be a high complexity, especially through assessment method (the interviews).
Physical Inter-dependence (PHI)	8. Low embeddedness 9. High disturbance 10. Somewhat tech uncertain	Somewhat relatable to transition theory, highly interdependent abatement options may indicate regime weak points, and thus a possible niche breakthrough. However, embeddedness is expected to be low, because the rules of the game and the playing field should be known by abatement option owners
Behavior (Beh)	11. High element of surprise, out of the scope 12. Frequent opportunities 13. Large changes in lifestyle, working habits	Somewhat relatable to transition theory. Pressure from different levels is needed to create an adaptive environment. Changing a sector, requires changing many individuals. Frequent opportunities helps with driving transition projects.

3. Six CO_2 abatement cases

"In the view of immense power of natural weather and climate fluctuations and the great buffering capacity of the Earth, specially the ocean, it is easy to be skeptical about whether small anthropogenic changes of atmospheric composition can have important practical impacts."
James Hansen, 1993

Introduction

In this chapter, the applicability of the Y-factor is explored through a series of abatement options in practice. Six cases studies are constructed of six abatement options. The Y-factor is used to determine the unit of analysis of the case study, but is also used as a crucial part of the interview template as an assessment framework. From 19 February 2018 to 11th April 2018, 23 interviews were carried out. However, two were incomplete and were not taken into account in further analysis. In total 21 interviews were analyzed for this thesis. All interviews were conducted face to face, except for two interviews. They were conducted via telephone, one due to practical constraints and another one due to scheduling changes at the last moment.

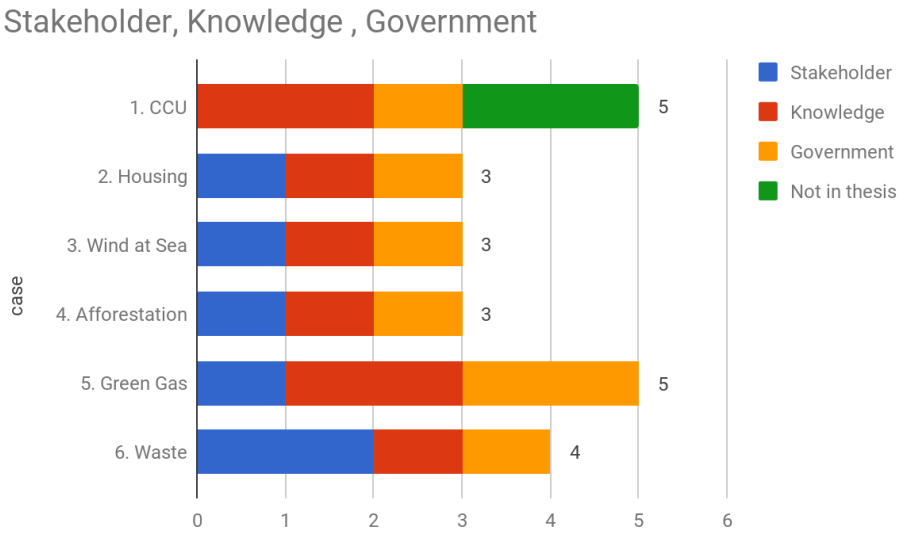

Figure 8 – Total interviews conducted for the Y-factor

The structure of this chapter

The structure of this chapter is as follows. Each subsection covers only one case study. Each case has been assessment in a semi-structured interview lasting about on average 1.5 hour using the interview guide and template created for each case. Transcripts are not used as a tool for analysis, but rather summarized instances of each interview. Each case study is structured in two parts: The case description part and the case analysis part.

The case description consists of:

- An introduction of a few sentences only. It briefly covers the scope, time, parties involved and recent media news of the case.
- An in-depth description from a technical and a social perspective. As argued from the systems perspective in section 2.1, this is deemed important. The technical perspective describes the situation, the demographics, the laws, the market, a breakdown of the technology, the value chain and the transition targets. The social perspective describes the problem owners, the citizens, organizations and governments, of the technology, their interests, their possible actions and their individual transition targets where possible.

The case analysis has the following parts:

- Keyword analysis: Summarizes the 13 factors of all interviews with keywords
- Categorical analysis: Presents conclusively the arguments for the 4 categories
- Perspective analysis: Presents the nuances by analyzing the perspectives
- Concluding narrative for the case and the score of the Y-factor.

On criteria of applicability and the research question

The research question as defined as RQ2 in chapter one is as follows: What is the applicability of the Y-factor on a variety of CO_2 abatement options? For determining the applicability of the Y-factor on abatement options, the approach is chosen to apply the Y-factor on six CO_2 abatement options and present their outcomes. In assessing the applicability, three criteria are chosen:

1. Level of understanding in practice
2. Usefulness for creating a case study
3. Level of constructive dialogue

The first criterion is about whether the interviewees understand the Y-factor. The second criterion is about whether the gathered interview data would allow for the construction of the case study. Finally, the third criterion is whether information between the interviewer and the interviewee has been exchanged. Was it a monologue, or was there a constructive dialogue? All three criteria are assessed based on my own perspective. For the first criterion, I pay attention to the introduction and start of the interview. Did I get the impression that there is misunderstanding. For the second criterion, I pay attention to the usefulness of the Y-factor assessment framework. I look at the possible comments about the framework and whether it easy for interviewees to give a score. For the third criterion, I assess whether dialogues were made instead of monologues.

The rationale for these criteria is that constructing a case study is difficult due to its many definitions (Swanborn, 2010), but mostly because a case study definition depends largely on the context and the research questions. Therefore the aim is to devise our own criteria for our case study. As all good things come in threes, three criteria constructed based on my own perspective, and each with a specific rationale. The first criterion is regarding the question interviewees have understood the research of the Y-factor and its interview questions. This is important, as having a mutual understanding of the same topic and the context of the topic, is one of the fundamental basis for a more in-depth follow up conversation. The second criterion is more practical towards my research, did the data gathering approach worked as intended? This is important for the study itself, as I want to know whether the Y-factor, and the whole

interview approach, work with gathering data for the case studies. The third and final criterion is related to the "purpose of communication". One could say that the purpose of a conversation is to exchange information. This is important for the process of the interview as a whole, because the goal is to go in-depth into the case. Without a fair or interactive conversation, the goal of going in-depth is far less likely to happen. I have derived this criterion from the Dutch principle "hoor en wederhoor" (or more globally known in Latin as "audi alteram partem"). Even though this principle has a more judicial origin and practicality, I believe this makes sense as a criterion in this case.

Two notions should be emphasized. First, the three criteria are assessed from own perspective in retrospect. Upfront, in the design of the interviews, four criteria are used to guide the interviews, they are similar, but the criteria is most focused towards managing the time and the dynamic of the interview. The four criteria are 1. "is there enough understanding?", 2. "am I able to fill in the Y-factor assessment framework?", 3. "are there hurdles, problems and comments?" and 4. "is the factor relevant"? Extensive analysis is therefore lacking of these upfront and in retrospect criteria. Second, the criteria are made for the purpose of creating individual and single case studies. For the goal of comparing multiple case study, other criteria could be more important, such as having a certain structure. For example, a structure that would produce the same type of answers, and thus having a certain consistency throughout the multiple cases. The structure should also provide a rigid reference frame, and should be understood (as much as possible) by everyone in the same way. This is discussed in chapter four more closely.

3.1 Case CCU

3.1.1 Case description (CCU)

Introduction

Scope: Project to setup an infrastructure for CO_2 transport from CO_2 sources to CO_2 consumers. The potential CO_2 savings are 0.6 ton from early estimation from the CO_2 users in the horticulture. The CO_2 transport is also for the storage areas offshore in the North Sea. The storage capacity is estimated to be quite high and good for tens of years depending on the annual output to these storage areas. A "CO_2 Smart Grid" project has been established in the North and South Holland of the Netherlands. The "Regeerakkoord", the Dutch cabinet's agreement, is talking about 18 Mton less CO_2 with "carbon capture and usage", however this did not specify any particular CCU project.
Time: A consortium was formed in 2016, by a Letter of Intention from various parties. The pre-feasibility study was finished around July 2017. At the time of preparing in January and February 2018, the TA and LCA were work in process. The SCBA was to be started shortly and the final project is to be completed in July 2018.
Involved: 21 parties: 4 governments, 14 private parties, 3 knowledge organizations. CO_2 sources, such as the harbor, waste incineration, steel factory, but also infrastructural partners, such as OCAP, and the CO_2 users, such as the horticulture members association, and the two Greenports in the Netherlands.
Recent media coverage : Port of Rotterdam's new offensive measure against CO_2 (FD, 2017), Biggest strategic blunder by the Port of Rotterdam in the past 10 years (VersBeton, 2017). CATO Meets the Projects event at TNO Utrecht (CATO, 2017).

Technical perspective
One of the new Carbon Capture and Utilization (CCU) project is nicknamed the "CO_2 Smart Grid". The project now is still mostly on paper, but around 20+ companies and governments have gathered to form a public-private consortium to back up this project. The feasibility of the

project is currently being examined (as of March 2018). The pre-feasibility study was interesting enough to conduct a more elaborate Technology Assessment, Life Cycle Analysis and a Social Cost Benefit analysis. CCU may be conceptualized into three parts: The CO_2 source, the CO_2 transportation medium (pipeline) and the CO_2 consumer market. The CO_2 sources may come from the heavy industry, such as the metal and the petrochemical industry. Carbon capture installations at the chimneys of factories will allow the capturing and filtering of CO_2 from the production process into liquefied CO_2. This process can be intensive and requires multiple (biochemical) processes like quenching the fumes (rapid cooling of gas), absorption (separating non-CO_2 gases), desorption (CO_2 released through a surface) and then finally compression, and stored in a buffer, waiting to be transported through an injection module into the pipeline or sometimes with normal trucks. In the Netherlands, an existing CO_2 pipeline exists, this is a pipeline between Amsterdam and Rotterdam of about 80 kilometers. The production process of a hydrogen plant has the byproduct of tens of tons of CO_2 per hour. The horticulture sector currently use about 0.4 Mton per year. The existing CO_2 pipeline makes use of this production process to deliver to CO_2 consumers. The current CO_2 Smart Grid plan is to extend the current pipelines through several smaller key projects. These smaller projects characterizes the three parts of CCU: capturing projects, distribution and storage projects, and reuse projects. From the preliminary study, the CO_2 demand in especially the horticulture result in an annual CCU potential of 1000 Ktons growing to 1.7 Mtons in 10 years' time, in the Dutch provinces of South and North-Holland. Differences in qualities of CO_2 and its pressure in the pipelines due to difference sources, may pose a challenge for the larger CO_2 infrastructure. Smaller CO_2 pipelines may exists, but it is unclear how many there are in the Netherlands as of now.

Social perspective

The "CO Smart Grid" is backed up by around 20+ private and public organizations in a consortium. The consortium consists of roughly three parties: governments, semi-private and private companies, and knowledge organizations. The governments are the Ministry of Economic Affairs, the Ministry of Infrastructure and Environment, two provinces; North-Holland and South-Holland. The semi-private and private companies in this consortium are the Port of Amsterdam and the Port of Rotterdam (partially owned by their respective municipality), "Natuur en Milieu Noord-Holland" and "Natuur en Milieu Zuid-Holland", two NGO with a public cause (in Dutch: ANBI), Amsterdam Economic Board, the Rotterdam and the Amsterdam waste incineration plant (partially owned by their respective municipality too) and a steel factory. Moreover, there are several association representing their members in the industry, such as the "LTO Glaskracht Nederland", Greenport Aalsmeer, Greenport Westland - Oostland (three horticultures associations), and Deltalinqs (an association of industry partners from the harbor of Rotterdam). Furthermore, transportation companies exists, such as the OCAP, a CO_2 transportation company, and Gasunie, a natural gas transporting company. Gasunie is partially owned by the state of the Netherlands. Last, but not least, three knowledge organizations as present as well, such as the TNO and ECN (research institutes) and BLOC (a company responsible for the process and development of a project). The current pipeline between Amsterdam and Rotterdam is owned by private company OCAP, and is fueled by a hydrogen plant in the harbor of Rotterdam. Pipelines under the ground are subjected to safety requirements by the Ministry of Infrastructure and Environment, the Dutch National Institute for Public Health and Environment, and the local Environmental Agency, such as the "Milieudienst Rijnmond". Pipelines in new areas need to be approved by the local municipalities it passes by. The installations at the sources, but also the CO_2-taps at the users requires the consent of the said stakeholders.

3.1.2 Case analysis (CCU)

Keyword analysis

On the left of table 7, the scores are given by the interviewees. The S stands for the stakeholder , the K is the knowledge organization, and G refers to a government perspective. The focus of the analysis is the set of thirteen subfactors, and present the relevant insights for each subfactor. Each score will be substantiated on the basis of the comments of the interviewees. However, if only the score of 2 is given, then there are only comments for the score of 2.

Table 7 – Keyword analysis CCU

S	K	G	Comments and arguments given for the subfactors scores.
2	2	2	**Investments costs?** [0=absent, medium, 2=large] (2) hundred millions of capex (capital expenditures), the process to initiate preliminary research already requires €0.5 million. Most often overlooked, and the biggest driver of costs are the storage facilities and the tap installations. Pipelines only are in the range of several millions.
2	2	2	**Payback period?** [<5yr, 5-12yr, >20yr] (2) The opex (operational expenditure) is very high, from €12 to €150 per ton. Even given current CO_2 prizes, investment costs can never be earned back
1	2	2	**Difficulty in financing?** [none, medium, large] (1) current smaller size CO_2 grids exists. (2) regional or national network is problematic. Might use one third of the annual budget for sustainable development.
1	0	2	**Number of actors?** [0=few, many, millions] (0) in principle the industrial chain, may be represented by the 20+ parties. (1) about thousands of Co2 buyers, the grid and infrastructures are lot less. (2) Many due to small and big public EU-tenders.
1	1	2	**How many dependencies on actors?** [0=none, few, 2=many] (1) business community and the horticulture associations (2) additionally tenders on EU-level
1	x	2	**Number of types of actors?** [low, medium, many/large] (1) local residents (2) ministerial, petrochemical associations, nature, and provinces
1	1	1	**Clarity roles?** [clear, slightly, unclear] (1) Newly formed ministerial “Climate Tables”. Several large CO_2 visions still up for debate. Climate Law in the near future.
2	2	1	**Physical embedded?** [0=none, medium, 2=strongly] (1) Embedded in public support for example through natural areas. (2) existing CO_2 pipeline, high clustered co2 demand.
2	1	x	**Disturbance regular operation?** [none, medium, many] (1) only disturbs the big users, the clusters. (2) disturbance in case of new extension pipelines.
1	1	1	**Technology uncertainty?** [proven, small, large] (1) TRL 3 to 6. New research needed for more efficient CO_2 storage, for example the “compensation stone”. Uncertainty in CO_2 application/use .
0	1	1	**Out of the scope?** [0=not, partially, 2=outside] (0) Not for port authority, horticulture (1) mostly within the scope is the consortium. Majority of the parties still partially out of the scope.

1	1	2	**Frequency of opportunities?** [often, medium, rarely] (1) Co2 consumers, are asking for it (Tata steel, horticulture, waste) (2) past opportunities exists, but act on it very slowly
0	2	2	**Behavioral change?** [no, slightly, large] (0) little changes for the co2 horticulture consumer (2) considerably changes for supply chain partner and for non-co2 users due to the new phenomena of CO_2 plants.

Categorical analysis (CCU)

The focus of the analysis is the set of four categories. The approach is to try to make sense of each category by condensing it into first one quantified subfactor and substantiate it with help of the keyword analysis. Each category is discussed in three: the subscores, the explanation of the subscores and eventually a conclusive narrative for the combined categorical score.

The CCU Case - Cost and Finance score: 1.9

The score is built up of the three sub factors related to one of the four categories of the Y-factor "cost and finance". The housing case has elements of high costs (2.0 as subscore), high payback times (2.0 as subscore), and high difficulties with financing (1.7 as subscore).

The capex for this climate measure is hundreds of millions. One of most significant drivers of the capex are the storage facilities, and the tap installations are the CO_2 sources. The most obstructing cost component is actually the high operational costs. According to assessments, the opex can be as high as €150 per ton CO_2. Financing CCU, is therefore difficult. The upscaling is mostly problematic, as smaller sized CO_2 grids exists in the Netherlands. The capital needed seems to be missing at the regional and mostly at the national level, as at the national level the budget is limited to €300 million for all sustainability initiatives

Overall, the costs for CCU is high. The business case is made negative by the large operational expenditures of capturing CO_2, but also by the large capital costs involved for the storage facilities and installing the CO_2 "taps". Financing is less of an issue for on a small scale, but the intended large scale rollout is problematic, as it would need an unjustifiable large portion of the public sustainability budget.

The CCU Case - Multi Actor score: 1.2

The score is built up of four factors related to multi actor category of the Y-factor. The CCU case has many actors involved (1.0 as subscore), of which few actors are seen as crucially dependent on (1.3 as subscore). The number of different types of actors in this case is seen as medium to high (1.5 as subscore), and the responsibilities in the CCU case is seen as slightly unclear (1.0 as subscore).

Many actors are involved, but not in the millions, hence the subscore of 1.0, which represent mostly the thousands of existing CO_2 consumers, but also the slightly more complex actors on a EU-level. The most critical actors are rather perceived as few rather than many. The CCU case is the mostly dependent on the few CO_2 producers, but also on small, and large (EU) tenders. Several other actors can be identified, but they are seen as medium in numbers. These actors are the local residents, the environmental ngo and provinces. The CO_2 business community is forming and converging into a single type of actor. However, there is a still a wider "inconvenient truth" for carbon capture and storage (CCS): Citizens do not see it as a solution, especially for the long term. Experts agree, but comment for reaching the climate goals in 2030 and 2050, CCU and CCS may be inevitable. For now, there is no overall master plan. The roles and responsibilities scores slightly unclear. The ministries have formed the "Klimaat Tafels", the seats are filled with actors from different sectors, disciplines and levels. These tables have work in progress roadmaps for a clearer vision, and plans for a national climate law in the near future.

However, for now there remains to be some degree of unclarities.

The Multi Actor Complexity is scored medium. The CCU case has many actors, but not millions. There are only few important actors, of which some are at the EU-level, and some converged and formed associations, such as the CO_2 (business) community. However, there is still a wider “inconvenient truth” that characterizes the CCU abatement option, but the case is becoming more clear with the help of a newly formed climate industry multi actor table at the national level.

The CCU Case - Physical Interdependencies score: 1.4

The score is built up of high physical embeddedness (subscore: 1.7), medium regular disturbances (subscore: 1.5) and medium technology uncertainty (subscore: 1.0).

The CCU case is highly embedded into the large clusters of horticulture, but also the existing pipeline network, the current CO_2 pipeline is actually an old oil pipeline. New pipelines, for extending the current CO_2 grid, under industry areas do not disturb significantly, but new pipelines crossing other areas would disturb the nature or civilians. Old pipelines might still disturb because of the installation needed at the CO_2 source (for example the steel factory), and the CO_2 consumers (the many CO_2 taps for horticulture). The technology for CCU overall can be characterized as medium. The carbon capturing technology exists, but mostly for small scale. Innovation for carbon capture in efficiency, new procedures and large scale deployment is needed. For carbon usage, research, prototypes and new (demonstration) products are needed. Sometimes the technology scale of TRL 3 to 6 is used for representing the technology uncertainties.

The physical interdependencies is scored medium. CCU is highly embedded in the oil infrastructure, but also in the horticulture cluster. In this CCU case, the physical disturbances are at the both ends of the pipeline, the tap-installations. CCU is somewhat dependent on technology as there are working solutions in practice already, but the technologies for large scale adoption are lacking.

The CCU Case - Behavior score: 1.1

The score for behavior is built up of partially in the scope (subscore of 0.7), medium frequency of opportunities (subscore of 1.3) and high behavioral change (subscore of 1.3).

In terms of behavior Y-factor, the CCU case has some elements of surprise for some actors, exemplified by the past cabinet’s agreement. But for some, i.e. the port of Rotterdam and the horticulture are looking forward to it for some time. For some parties, CCU is still partially out of the scope, one consortium sees this low awareness among different businesses, and one of their aim is to work towards higher awareness for CCU and its CO_2 potential for the business community. The opportunities in the sector are actually quite rare, this could be said for both the CO_2 opportunities as well as generally business opportunities. The governments and related market parties (for example the steel industry) do not grab these CO_2 opportunities by themselves in isolation. Exceptions exists, so there are few frontrunners. The behavioral changes that CCU brings along are small for the CO_2 end-users in the horticulture. However, the CCU case implies a change of economy, the addition of a new CO_2 market. This affects the way of working for the supply chain partners. As a result, these new facilities and plants might entail unforeseen behavioral changes from the public too.

The CCU case shows medium behavioral elements. For most actors, the CCU is something they have in their scope for quite some time. While some parties in the CCU sector are acting as frontrunners, the sector in general is somewhat slow in taking advantage of CO_2 opportunities. The behavioral changes that CCU might entails after roll-out can be quite high, as a new market with all its dynamics will emerge.

Perspective analysis (CCU)

The perspective analysis is about the differences between the scores of the perspectives. A radar chart is used to help visualize the range of these differences and the general match between the perspectives. For the case, it is important where the main differences and similarities are, but it is also important to know that these results are all relative to each other. The focus of this analysis would be on each of the four category and find out about the largest and the smallest differences. A ranking relative to each other may be presented if interesting. Only the results of the categorical analysis and the radar chart tables will be used for analysis. If the radar chart reveals interesting points, this could be taken along too for the narrative.

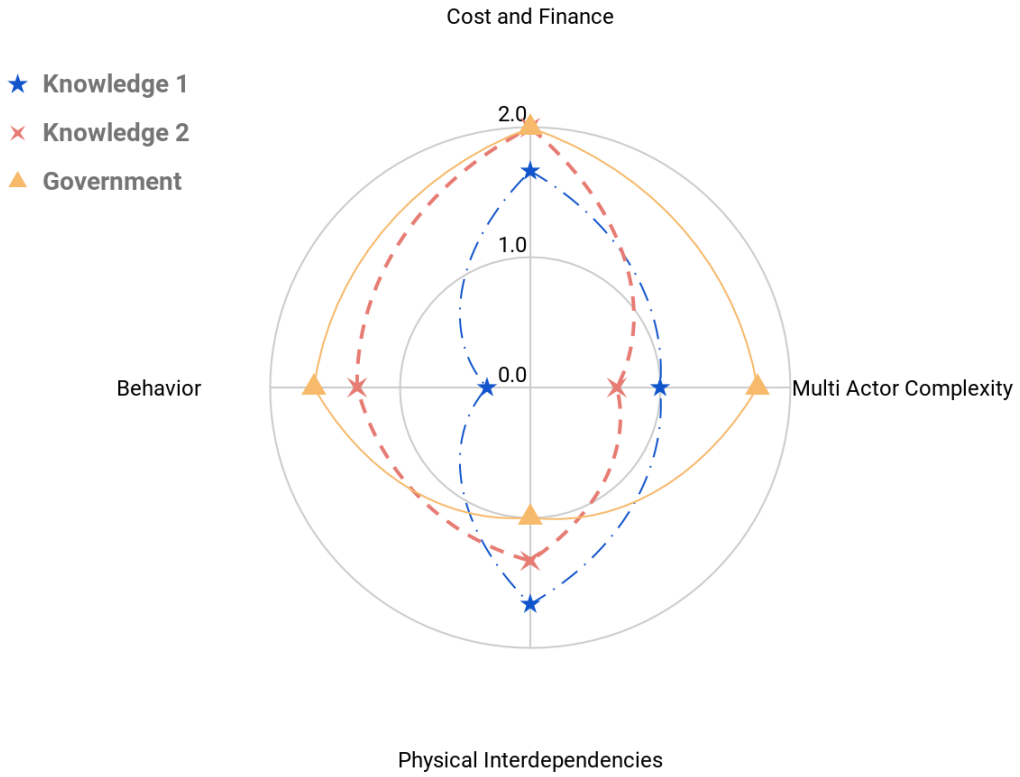

Figure 9 – Perspective analysis CCU

In the CCU case, the stakeholder perspective is missing. There are two knowledge organizations and one government interviewed. A spider chart is used as a tool for the perspective analysis.

First, the overall differences of the perspective is analyzed by looking at the inner circles and the outer circles. The two knowledge perspective should overlap more. This is true to a certain degree, the government perspective never comes in between the two perspectives lines. The total score of the two knowledge perspective is also closer to each other than to the government. From 4.7 to 5.3, as opposed to the total score of 6.4 of the government. As for the inner circle and the out circle, this radar chart does not provide a clear and apparent answer. Based on the overall score, the knowledge perspective forms the inner circle and the government perspective forms the outer circle. This could mean that the government perspective generally sees more elements (of the Y-factor) than the knowledge perspective, in this single case.

Second, one can look at the differences and similarities by looking at the range of each category. The range in Finance & Costs is quite low (0.33). The only overlapping point of the radar chart is in this category. The three interviewees agree almost unanimously that the scores are all 2. Then, the range of Physical Interdependencies follows with a range of 0.67. Up next, is the Multi Actor Complexity category with a range of 1.1. This is mostly caused by the “knowledge 1” interviewee, with mostly 1 scores, and the government with

most 2 scores. The category with the largest range is that of Behavior, the range is 1.33. This is mostly caused by the relatively low score of the “knowledge 1” interviewee (0.3), and the government interviewee (1.7).

Concluding narrative and on applicability (CCU)

The concluding narrative has a twofold structure by first combining the concluding remarks of the categorical and the perspective analysis only. This allows for more nuances of the case specific categorical analysis shown before. The focus is on explaining the quantified subscores and the final Y-factor of the case.

The Y-factor for the heavy industry case, based on this single CCU case is 1.9 + 1.2 + 1.4 + 1.1 = 5.6. These subscores are respectively based on the category of cost and finance, multi actor complexity, physical interdependencies and behavior.

Overall, the costs for CCU is high. The business case is made negative by the large operational expenditures of capturing CO_2, but also by the large capital costs involved for the storage facilities and installing the CO_2 “taps”. Financing is less of an issue for on a small scale, but the intended large scale rollout is problematic, as it would need an unjustifiable large portion of the public sustainability budget. For this case, the knowledge and the government perspective are examined, the two perspectives agree highly with each other in this category of the Y-factor.

The Multi Actor Complexity is scored medium. The CCU case has many actors, but not in the millions. There are only few important actors, of which some are at the EU-level, and some converged and formed associations, such as the CO_2 (business) community. However, there is still a wider “inconvenient truth” that characterizes the CCU abatement option, but the case is becoming more clear with the help of a newly formed climate industry multi actor table at the national level. The two perspective for this case is relatively high for this case, the knowledge perspective sees lower amount of actors whether dependent or not. The government perspective sees more types actors demographically as well as dependent actors, mostly from the more complex EU-level.

The physical interdependencies is scored medium. CCU is highly embedded in the oil infrastructure, but also in the horticulture cluster. In this CCU case, the physical disturbances are at the both ends of the pipeline, the tap-installations. CCU is somewhat dependent on technology as there are working solutions in practice, but the technologies for large scale adoption in pilots and demonstration projects. The two perspectives differ relatively little in this case. They unanimous agree in terms of technology uncertainty. At most, the two perspectives differ in the daily disturbance subfactor.

The CCU case shows medium behavioral elements. For most actors, the CCU is something they have in their scope for quite some time. While some parties in the CCU sector are acting as frontrunners, the sector in general is somewhat slow in taking advantage of CO_2 opportunities. The behavioral changes that CCU might entails after roll-out can be quite high, as a new market with all its dynamics will emerge. The two perspectives differ the most in this category. The largest difference can be found between the behavioral changes when CCU is present; the knowledge perspective seem to foresee much less changes for the users and the end-users, while the government perspective sees more changes due to the frame of a new CO_2 market.

The applicability of the Y-factor for this case is considered as medium. The Y-factor assessment framework is generally well understood. The usefulness of for the case study is lower. An important actor perspective is missing; that of the stakeholder’s perspective. Two interviews were too incomplete to be included in the analysis. However, both with different reasons, one was more held back due to the topic’s controversy, and one was more held back by not fully agreeing with the questions. It could be said that in the former case, the Y-factor approach was less useful, and in the latter, the Y-factor did not provided enough foundations for a constructive dialogue. Both outcome of the interviews could also be due to inherent

limitations of interview as a data collection method. In the interviews that were carried out completely, the dialogue did feel as if it was constructive. Information sharing between both the interviewee and interviewer is experienced.

3.2 Case Housing

3.2.1 Case description (Housing)

Introduction

Scope: The nationwide ambition to renovate housing to be more energy efficient. The goal is to reduce the energy (gas) use. Two ways are generally possible, through isolation and installation. Isolation is about the floor, facade, roof, windows and more. The installation is about the boiler/heat pumps for the central heating system and warm water. It could also be about better air ventilation, and with upgraded solar boilers and PV-cells upgrade among others.
Time: continuous process of energy saving and thus CO_2 reduction measures. Ambition of cabinet now: 30-50k existing households gas-free upcoming 4 years. Longer term goal is 200k housing per year, to fulfill 2050 goal of 6 million existing housing 2-3 Mton feasible
Involved: individual households, housing corporations, local and regional energy collectives
Recent media news: A recent research called “Installatie 2020” has come to an end, Nul op de Meter

Technical perspective

The Netherlands has around 7 million households. About one-third of the households are social housing, and the rest is the free or private housing market. A significant proportion of the buildings are built between 1945 and 1975 (2.5 million), and there is a large category of buildings with the build year 1945 or before (1.5 million) (MinBZK, 2016). Renovating or refurbishing these houses to be more CO_2 or energy friendly by means of better installations is therefore not that straightforward. Energy label are sometimes used to indicate that a house is more energy or CO_2 friendly.

The idea is that increasing 5 households one energy label, would be better or equally good as increasing one household 5 energy labels. Refurbishing new houses are more easily, if not unnecessary as they have already a high enough energy label. Often new houses already have the most recent and sustainable requirements. However, sometimes new houses are transformed from other buildings types and refurbishment is needed. For example through repurposing an area with office buildings, shops or others. Every year, a portion of social housing are sold too. Roughly 20k social housing and 30k private housing are built new per year, and roughly 15k are bought from social housing per year. Independently from these numbers, the trend of the total housing stock in the Netherlands can be said to increase with around 45k to 55k per year since 2014, with around 75k to 85k new housing every year, and about 25k to 40k houses removed from the housing market every year (MinBZK, 2017, page 14).

Comparing mutation numbers per year and the following ambitious targets of refurbishing around 200k housing per year (to a total of 1.6 million housing refurbished in 8 years to a higher energy label), the natural background movement of a more sustainable housing market is often seen as the "do nothing" option, or the base scenario (Schilder, 2016, p. 10). To reach those targets, the type of dwellings also matter for refurbishing. A detached single-unit housing is very much different from an attached multi-unit housing. There are also semi-detached dwellings. Generally refurbishing dwellings can be done through isolation, such as better walls, windows, floors among others, but also through advanced energy installations, such as hybrid heat pumps, and PV-cells. The Dutch have developed a "NOM" industry standard around 2013, and it refers to the "Nul op de Meter" or a "net zero energy" refurbishment. This type of refurbishment delivers dwellings with a zero energy use on

balance, and as a consequence, zero CO_2 emission as well. In 2015, more than 500 NOM buildings were completed and more than 8000 are in realization phase.

Social perspective

Out of 7 million households in the Netherlands, there are around 369 housing corporations that are responsible for 2 million social housing. Housing corporations are chartered to serve a public good, and that is to provide affordable housing for people with relatively low income. Housing corporations have changed institutionally significantly since its inception in the Netherlands in the 1850. Various laws came into place to ensure more qualitative social housing than before, such as the Woningwet in 1901, the Bruteringswet in 1994, and the Herzieningswet in 2015. Housing corporations have to work with municipalities and tenants associations to come to an agreement about the performance they are going to deliver for the tenants down the road. Private housing are not subjected to these rules, but private houses have to be part of an homeowners associations (Dutch: VvE). There are around 144k homeowners association in the Netherlands (2015). Both housing sector fall under the responsibility of the Ministry of Binnenlandse Zaken en Koninkrijksrelaties. Other organizations exists to facilitate parties to be more in control and more transparent in pursuing the welfare of the tenants, as well as the private homeowners, such as the Autoriteit Woningcorporaties, and the Kadaster among others. For more specific CO_2 oriented organization, local energy initiatives sometimes materialize to realize more sustainable refurbishments, through the advantage of more economies of scale and more organizational leverage. For example, in 2013, parties (with help from a very large energy initiative: Energiesprong) brokered a deal between 6 housing corporations and 4 construction companies to realize 11.000 NOM. In 2015, more than 500 NOM buildings were completed and more than 8000 are in realization phase. In pursuing similar goals, the initiative “Stroomversnelling” partnered with even more partners to realize a more ambitious goal, namely 100.000 in the rent housing sector.

3.2.2 Case analysis (Housing)

Keyword analysis

On the left of table 8, the scores are given by the interviewees. The S stands for the stakeholder , the K is the knowledge organization, and G refers to a government perspective. The focus of the analysis is the set of thirteen subfactors, and trying to make sense of each subfactor through the comments given by all the interviewees.

Table 8 – Keyword analysis Housing

S	K	G	Comments and arguments given for the subfactors scores.
2	1	2	**Investments costs?** [0=absent, medium, 2=large] (1) around several thousands. (2) from 15k to 80k
1	1	2	**Payback period?** [<5yr, 5-12yr, >20yr] (1) Longer payback times aren't accepted. Needs to account for uncertainty in future electricity price. (2) some projects simply won't have a reasonable return on investment.
2	1	0	**Difficulty in financing?** [none, medium, large] (0) not only stable cash flows and collateral, but also through financial structures, such as the EPC (Energy Performance Contract), within their corporation-network (1) have reserves and can afford bigger loans (through collateral). (2) no collateral at all (e.g. for the VvE’s, the homeowners associations), some mortgages are “underwater”.
2	2	2	**Number of actors?** [0=few, many, millions] (2) largely fragmented installation sector, only so few big installation companies. 2+ million households are represented by 300+ housing corporation, but 5+ millions households are only

			represented by themselves or the homeowners associations (100.000+ VvE's in NL).
2	2	2	**How many dependencies on actors?** [0=none, few, 2=many] (2) large dependency on construction workers and contractors. Fragmented and they are dependent on economies of housing sector,.
2 S	2 K	1 G	**Number of types of actors?** [low, medium, many/large] (1) three actors; municipality, occupants and the corporation (2) renovation vs new housing movement and the poverty vs sustainability for most of the social housing.
0	2	1	**Clarity roles?** [clear, slightly, unclear] (0) clear roles, and clear strategy; "wait and see". (1) "slow turning radars" referring to unaligned actors in the installation sector.(2) unclear in the many approaches for renovation.
2	2	2	**Physical embedded?** [0=none, medium, 2=strongly] (2) embedded in characteristics of building. Dependent on "street image". Dependent on monumental buildings. Within one flat or complex some houses might differ significantly, e.g. ownership different, or structurally different.
2	2	0	**Disturbance regular operation?** [none, medium, many] (2) requires "renovation-factory", temporary relocation of occupants, bigger than the neighbor's house, (0) if compensated, there is no disturbance
1	1	1	**Technology uncertainty?** [proven, small, large] (1) available in the market, much proven-tech, but small adoption by the market. Needs to mature to drive down costs and usability.
2	0	1	**Out of the scope?** [0=not, partially, 2=outside] (0) housing sector is involved for years, especially since 2000. (1) sustainability on agenda, but not as high since climate accord. (2) for the construction and installation, its much outside their agenda.
2	1	0	**Frequency of opportunities?** [often, medium, rarely] (0) corporations do get such opportunities often, since some time ago a law made them financially independent (1) corporations, but also private owners can be quite opportunistic and be entrepreneurial through neighborhood initiatives (2) renovation occurs 20-40 for the local parties, it's always tailored work. They do not get these opportunities often.
2	2	2	**Behavioral change?** [no, slightly, large] (2) neighbors need to adjust to more "innovative" house next to them. Occupants themselves as well, due to the rebound effect of the slow systems; sometimes energy use is higher. Different air and noise quality, not perse bad, but just different. Game changer for the constructors and builders: from product to end-to-end project mindset.

Categorical analysis (Housing)

The focus of the analysis is the set of four categories. The method is to try to make sense of each category by condensing it into first one quantified subfactor and substantiate it with help of the keyword analysis. Each category is discussed in three: the subscores, the explanation of the subscores and eventually a conclusive narrative for the combined categorical score.

Housing Case - Cost and Finance score: 1.3

The score is built up of the three sub factors related to one of the four categories of the Y-factor "cost and finance". The housing case has elements of high costs (1.7 as subscore), medium to high payback times (1.3 as subscore), and medium difficulties with financing (1.0 as subscore).

The investment costs for the case can be very different in absolute terms. It all depends on the characteristics of the building, they vary from several thousands to 80k or more. From

the perspective of the tenant or owner, this is generally experienced as high. Long payback period are not accepted. However, some costs for the installations may have an very long roi. The financing part seem to easy as well as difficult. This depends on the collateral that one possesses. The more stable cash flows, reserves among others, the easy it is for financing. However, some mortgages are underwater and have therefore have low to no collateral.

Overall, the cost and finance factor for the Y-factor is 1.3. It leans more towards to a medium score, rather than the high score. This is because the investments can be low, and installations are designed for shorter payback periods, and the housing case shows that there are means to finance it, but that doesn't account for every type of building.

Housing Case - Multi Actor score: 1.7

The score is built up of four factors related to multi actor category of the Y-factor. The housing case has many actors involved (2.0 as subscore), of which again many actors are seen as crucially dependent on (2.0 as subscore). The number of different types of actors in the housing case is seen as high (1.7 as subscore), and the responsibilities in this case is seen as slightly clear (1.0 as subscore).

The elements for the multi actor complexity sub factor of the Y-factor seems to be mostly high in the housing case. The number of actors are in the millions, and the dependent actors are far too many too for the interviewees, referring mostly to the fragmentation in the installation and construction sector. Wider economic conditions may change the pool of construction companies to work with, as a significant portion will then stray away from the more difficult renovation projects with usually lower profit. Crucial actors in this fragmented landscapes are the teams of multidisciplinary professionals (consisting of at least 10 persons), for each housing corporation. There are more than 300+ in the NL. The number of different types of actors are experienced as high, but may be grouped in three essential actors: the municipality, the housing corporations and the occupants. The roles in the housing case are slightly unclear. For some the unclarity is in how to be in alignment with the installation sector. For some, it is the different approach for different types of renovation in different neighborhoods. There is a general discussion of affordable living goals (poverty, old housing) versus climate goals.

The housing case shows a high degree of multi actor complexity. The underlying aspect of having to initiate, design and tailor make the for every housing unit or complex is daunting; there are millions of households to transform in order to transition into a low or zero carbon housing sector. The capacity in terms of teams of multidisciplinary energy consultants, and the amount of installation and construction contractors are far too low. The clarity of roles is experienced as medium, as generally the housing sector is clear on its aims, but the necessary partners, such as actors from the installation sector, are not.

Housing Case - Physical Interdependencies score: 1.4

The score is built up of high physical embeddedness (subcore: 2.0), medium regular disturbances (subscore: 1.3) and medium technology uncertainty (subscore: 1.0).

The housing case is characterized with high embeddedness within other systems, such as the street image, monumental buildings, but mostly with the many characteristics of a building (usually sorted by age and type of dwelling). The installations might disturb other systems as well; occupants may have to relocate temporary, and could disturb the rest of the street. However, solutions, such as compensation have shown to work in pilots. The technology used is medium, it is proven-tech, and available on the market. However, there is very low market adoption, an estimated 0.5% of the market has similar installation. This might be due to the installations products are dependent on the global market as well. In any case, there is a need for mass fabrication and make use of economics of scale to drive down the costs.

With a score of 1.4, the housing case is characterized by medium to high degree of interdependencies. There are many types of housing, as well as the many types of neighborhood a house is in seem to drive the score up. Additionally, the occupants need to

relocate most of the times, and are therefore quite disturbed. This also increases the significance of this factor. The technology isn't an issue from a technological point of view, but technologies that could drive down the cost price is very much needed.

Housing Case - Behavior score: 1.3

The score for behavior is built up of partially in the scope (subscore of 1.0), medium frequency of opportunities (subscore of 1.0) and high behavioral change (subscore of 2.0).

The housing sector doesn't seem to be surprised by the climate accord. Most housing corporation have experience working with municipalities and the ministry quite closely. The installation and the construction sector, on the other hand are not. They seem to struggle keeping up with the innovation-driven demand from the housing sector. It is not that the installation and construction sector does not have frequent opportunities, but that they are in smaller numbers and often tend to go for the easier and more profitable new housing. Renovations only happen for 20-40 years, and for the local stakeholder the frequency is low. Corporations and some neighborhoods with an entrepreneurial character do experience more opportunities. In terms of behavioral changes, large changes can be seen for the occupants, but also the contractors from the installation and construction sector. The installation and construction sector are required to work differently too: away from a simple product delivery with turn-key contracts, towards a more comprehensive and collaborative project approach with performance-based contracts. For the occupants, the air quality and the sound quality of the installation changes too. This is not as in lower quality, but it is more of a change of habits. Sometimes, this may even affect the business case of the installation, as energy consumption might go up due to a known “rebound effect”.

In conclusion, the behavioral score is medium to high, 1.3. The housing sector is partially surprised, and have somewhat frequent opportunities. But the behavioral changes are experience as high nevertheless, especially for the end-users of the systems, and the installation and the construction contractors.

Perspective analysis (Housing)

The perspective analysis is about the differences between the scores of the perspectives. A radar chart is used to help visualize the range of these differences and the general match between the perspectives. For the case, it is important where the main differences and similarities are, but it is also important to know that these results are all relative to each other. The focus of this analysis would be on each of the four category and find out about the largest and the smallest differences. A ranking relative to each other may be presented if interesting. Only the results of the categorical analysis and the radar chart tables will be used for analysis. If the radar chart reveals interesting points, this could be taken along too for the narrative.

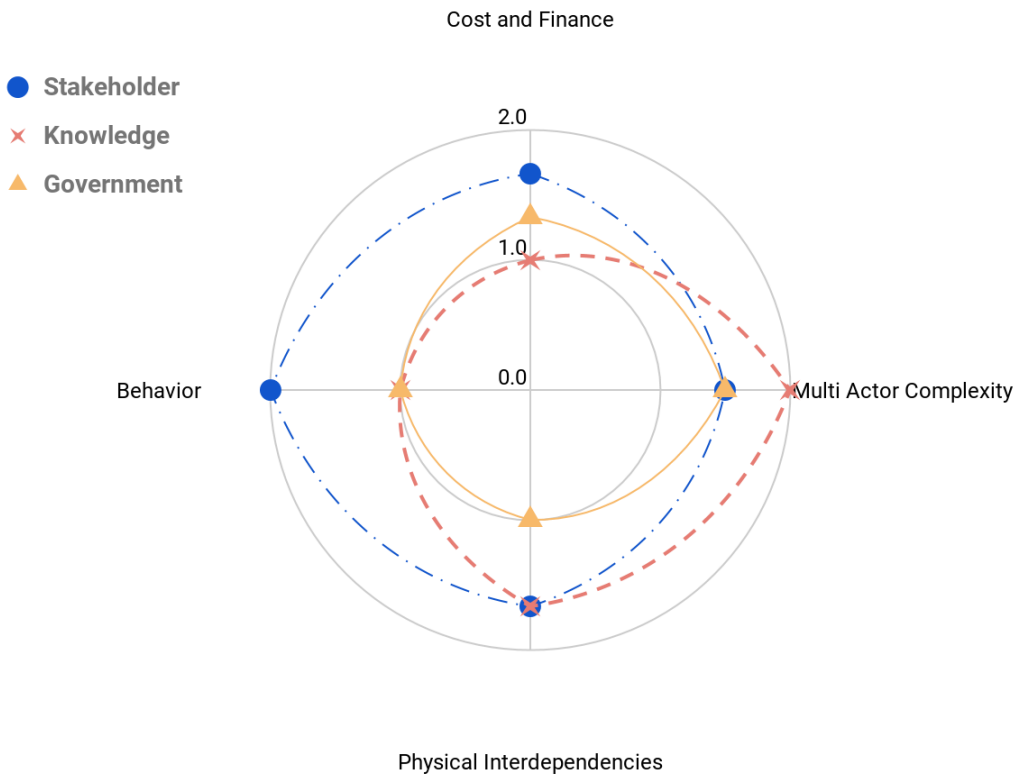

Figure 10 – Perspective analysis Housing

In the housing case, one stakeholder, one knowledge organization and one government are interviewed.

First, the differences and similarities between the perspectives in a quantitative way are discussed. An indication of the relative range between the three interviewees can be given. The largest differences can be found in “behavioral” between the four interviewees, with a range of 1. Then followed by “finance & costs” with a range of 0.7 (from 1.0 to 1.7), and “physical interdependency” with also a range of 0.7 (from 1.0 to 1.7). The most similar category among the perspective is “multi actor complexity”, which has with a range of 0.5 (from 1.5 to 2.0). The perspective with the highest score is that of the stakeholder, with a combined score of 6.8, as opposed to knowledge (5.7) and government (4.8).

Second, one can look at what stands out visually. There is no obvious inner circle nor outer circle, but the government would most likely fit the inner circle description, and respectively the stakeholder would fit the outer circle description. The Multi Actor Complexity somewhat stands out, because all perspectives seem to cluster there with their relatively small differences in scores. Another observation is that no scores are below 1, and all scores are between 1 and 2. The scores also overlap with each other quite often (3 times), and cross each only in between finance and costs and multi actor complexity. From looking at the visuals, the perspectives can be said to cohere quite well with each other, except for the behavior category.

Concluding narrative

In this concluding narrative analysis, the conclusions of the categorical analysis and the perspective analysis will be combined. This allows for more nuances of the case specific categorical analysis shown before, by adding the perspectives.

The Y-factor for the housing case is 1.3 +1.7+ 1.4 +1.3 = 5.8. The scores are respectively based on the category of cost & finance, multi actor complexity, physical interdependencies

and behavior.

The cost and finance factor for the Y-factor is 1. This medium score is represented in capital investment from several thousands to 80k. This is seen as relatively high, but most of the time this can be earned back around 10 years. The housing case shows financial structures that are present and while they are hard to get, they are available and for housing corporation they are more accessible than for private housing. The perspective analysis shows somewhat differences in the scores, but generally acknowledge a nuanced picture of the investments costs, and the finance ability, while generally agreeing on a medium payback period.

The housing case shows a high degree of multi actor complexity. The absolute numbers of involved actors are experienced as daunting; millions of households need to transform in order to acquire that transition to low or zero carbon housing sector. The actors that the case is most dependent on are seen as high. There are too many projects to be executed then there is teams energy consultants. The fragmented installation and construction contractors is far too high too, making the dependency with actors even higher. There are many types of actors with different interests, the tenants distrust the corporations, and there is a certain imbalance between renovation vs new housing. The clarity of roles is experienced as medium, as generally the housing sector is clear on its aims, but the necessary partners, such the installation sector and the tenants, are not. In the perspective analysis, all three perspectives agree on that there is a high degree of multi actor complexity. Two interviewers make the remark that it is crucial for the many “gears” (in Dutch: “radartjes”) to be of the same speed, if one slows down, everything slows down or might even come to a hold.

The housing case is characterized by a medium degree of interdependencies. Whether renovation or new installations in a house or housing complex are done, depends on not only the age and characteristics of the building structure, but it also depends on the street and the city’s urban plan. Special buildings, such as monuments, may never be renovated in such a way. Moreover, at times of construction, it is likely that the occupants need to relocate. This is not always feasible. The dependency with technology is experienced as medium, it is proven-tech, but new energy concepts are said to be required to drive the costs down and increase adaptation. The three perspectives agree with each other in that the case is highly embedded and that the technology level is medium. In physical embeddedness, one perspective commented on that there are many small problems, and they may stack up considerably to form a big problem. The perspective do not agree whether the disturbance to daily business is high or low.

The behavioral score is medium. The housing sector is partially surprised, and have somewhat frequent opportunities, but the behavior changes for the occupants and the contractors drive this score up. From the perspective analysis, the behavior score has the biggest range, so the interviewees’ scores differ the most, but all agree to a high amount of changes in behavior for the occupants and a “game changer” for the contractors.

The applicability of the Y-factor on this Housing case, could be said to be high. The level of understanding for one of the interviewees was very high. She knew various colleagues facing similar issues. The collected data seems to be useful for constructing the case study, and for every interview, the level of dialogue seems to be constructive.

3.3 Case Wind at Sea

3.3.1 Case description (Wind)

Introduction

Scope: Additional offshore windparks location in the North Sea, with the aim to have 4 Mton CO_2 abated. The areas in the North Sea considered for wind parks are the "Hollandse Kust”, “Noorden van de Waddeneilanden”, “IJmuiden Ver” en “Borssele”.

Time: The 4 Mton of CO_2 reduction should represent around 11.5 GW of wind energy by 2030
Involved: The maritime transport, fishing industry, the onshore actors, the grid operator, the wind engineering companies, and more.
Recent media news: Currently three areas for the windparks are selected: Hollandse Kust Noord, and Zuid, and Borssele. The Dutch environmental assessment agency make notice that the new offshore windparks are supported by a competitive subsidy budget and make further notice that the development of "Wind op Zee" is limited not by the available physical area in the North Sea, but by limiting budget.

Technical perspective
The Netherlands has around 9.5 GW offshore wind energy already in 2017. Four locations has been designated for these offshore wind parks. The two earliest ones are built in 2008 and are called “Prinses Amaliawindpark” and “Windpark Egmond aan Zee”. The costs of the most recent windpark in 2017 was around the 2800 million euros, with a capacity of 600 MW. This is around 4.7 million euro per MW. Typical offshore wind turbines are 4 MW. As of 2018, new locations in the North Sea are assigned for windpark projects. For installing offshore wind parks, a power grid has to be extended from the shore for the energy distribution. Sometimes the analogy with “power outlet on sea” is used to indicate the efforts for connecting the windparks with the inland energy grid. For energy transportation, a high voltage is needed for a high efficiency transport. Therefore, the power cables at sea operate at the high voltage. For home and business use, smaller in between energy stations are needed to lower the voltage and distribute among users. For aligning the demand and supply on the energy grid, energy market exists. Energy markets are similar to that of the stock exchange, it has hourly and minute prices, this is because energy may be transported with the speed of light, and energy storage is expensive. For redundancy and stability of the power grid, connections are made with neighbor countries. The North Sea is not an empty space. Rotterdam is one of the world most busiest ports and the North Sea has many navigation routes. Other construction exists offshore, such as oil and gas platforms. The construction of a wind turbine is large undertaking. For example, the foundations have to be made, perhaps with concrete enforcement due to weak seabed floor. The steel construction, but also the engine and the wind turbine blade. Maintenance offshore is quite expensive.

Social perspective
In the Netherlands the Ministry of Economic Affairs and Ministry of Infrastructure and Environment have the authority over the North Sea area. The North Sea area is used by various stakeholders, such as the navy and the military, but also the international trade, and their marine routes, the oil and gas companies, see figure 11 for an overview in the form of a map. Furthermore, environmental zones exist for biodiversity, and near the coast, coastal communities may be affected, as wind parks can be seen with the naked eye from the coastline. For these functions and interests of the North Sea, a (public) consultation process is needed. This process usually starts with the project developer drafting an “environmental impact assessment” report (in Dutch: milieu effecten rapportage). Different countries may differ in the specificities of the environmental impact assessment, but in the Netherlands the report needs to take into account all the environmental consequence before the government can take a final decision making for the project. Depending on the exact project, the public needs to be involved. In the Netherlands, two types exist the extensive procedure and the limited procedure. After the allocation decision for the exact space and area at sea, a process of tendering follows. A request for tender is a formal and structured invitation for market parties in the line with the competition regulation to ensure a more fair and transparent process. Various companies in consortium apply for the tender. Winning a tender means adding additional energy production capacity to the power grid. The value chain of energy consists of various parties generating electricity, such as gas plants, but also hydropower plants among others. The transmission lines are the next important value chain. Electricity is transformed into high voltage for efficient transport. Then when the transmission lines reaches urban areas, the distributed system operator (DSO) are responsible for converting the voltage back for safe

household and small business use. In the Netherlands, the transmission company is public and is a natural monopoly, the DSO are semi-private, and there are several DSO in the Netherlands.

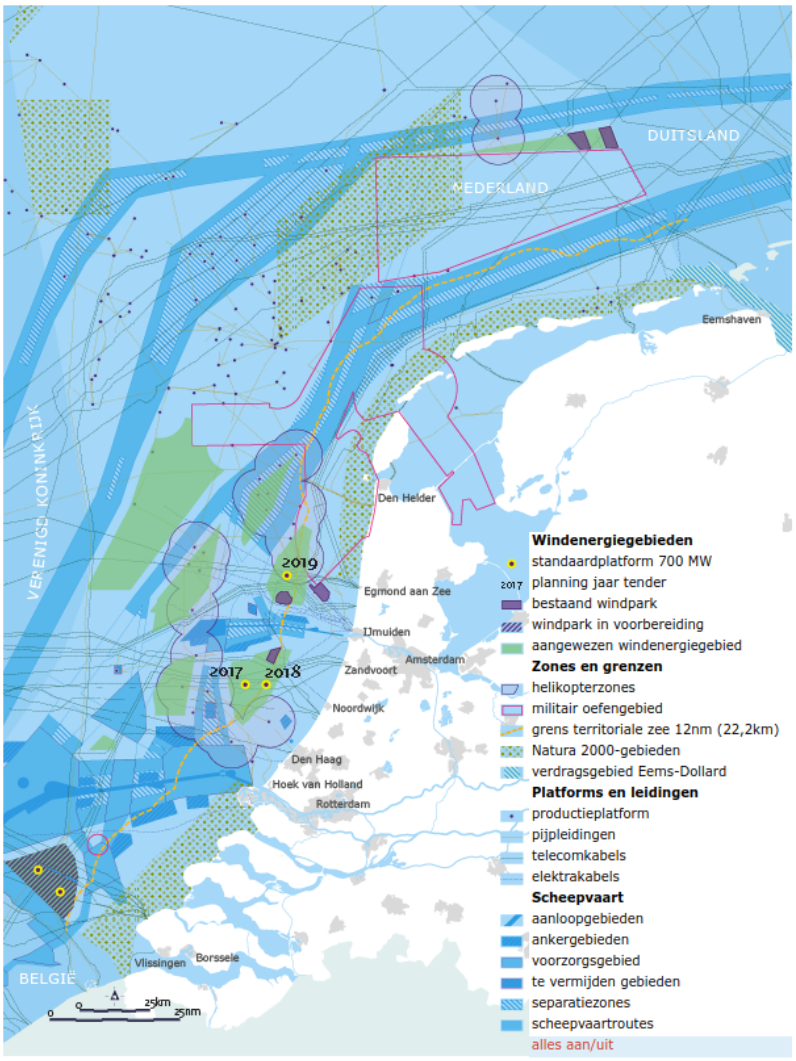

Figure 11 – The crowded North Sea irt the Wind at Sea case

3.3.2 Case analysis (Wind)

Keyword analysis (Wind at Sea)

On the left of table 9, the scores are shown from each interviewees. The S stands for the stakeholder , the K is the knowledge organization, and G refers to a government perspective. The focus of the analysis is the set of thirteen subfactors, and trying to make sense of each subfactor through the comments given by all the interviewees.

Table 9 – Keyword analysis Wind

S	K	G	**Main motivation for the score?**
2	2	2	**Investments costs?** [0=absent, medium, 2=large] (2) average €2 million per MW. Ambition is additional 7 GW, making a total of 11.5 GW. So 7 GW is roughly €14 billion.
1	1	x	**Payback period?** [<5yr, 5-12yr, >20yr] (1) designed for around the 10-12 years

0	1	0	**Difficulty in financing?** [none, medium, large] (0) windpark on sea first time without subsidy (1) requires subsidy
x	1	2	**Number of actors?** [0=few, many, millions] (1) workforce of 20k and more soon increasing to 150k. (2) coastal communities, and the international navigation routes, the installation sector and nation and european demand for wind energy.
1	2	1	**How many dependencies on actors?** [0=none, few, 2=many] (1) few, sometimes 1 company can already win the tender and build the project. (2) many stakeholders for location decision.
1	1	1	**Number of types of actors?** [low, medium, many/large] (1) existing procedures bring people together. There are formalized and well known stakeholder channels. Stakeholders are more organized on sea than on land. Few oppositions.
0	1	1	**Clarity roles?** [clear, slightly, unclear] (0) grid responsibilities are clear (1) stakeholders roles in the wind park procedures are clear, due to alignment with three ministry and good existing, but also new “omgevingswet” (environmental law).
2	2	2	**Physical embedded?** [0=none, medium, 2=strongly] (2) North Sea is a busy place to build; many navigation routes, pipelines, military functions and coastal communities.
2	0	2	**Disturbance regular operation?** [none, medium, many] (0) after permits there shouldn't be any disturbance (2) disturbance on the nation, but also european power grid. Construction phase may be very large and need to be concerted.
0	0	1	**Technology uncertainty?** [proven, small, large] (0) platform and cable technologies are high in the technology level for decades. (1) some demonstrations of “zero-maintenance” innovations, however “Gas meets Wind” and “Chem on Sea” are still in R&D. But current windparks could survive without these technologies.
1	0	0	**Out of the scope?** [0=not, partially, 2=outside] (0) lots of industry wide agreements already (3rd energie akkoords) (1) grid operators are aware, but do not take active role in cabinets agreements.
0	0	0	**Frequency of opportunities?** [often, medium, rarely] (0) grid operators follows the policy cycles. Market is experienced with wind parks all of the world. The NL gov has also experience, as well as the coastal communities due to several windparks already before.(two in 2008, 1 in 2015 and 1 in 2017.)
0	1	2	**Behavioral change?** [no, slightly, large] (0) perhaps only visual pollution, 3D imaging for stakeholder meetings (1) increased tourism for coast communities to adapt to (2) requires the wider societal change of electrification.

Categorical analysis (Wind at Sea)

The focus of the analysis is the set of four categories. The method is to try to make sense of each category by condensing it into first one quantified subfactor and substantiate it with help of the keyword analysis. Each category is discussed in three: the subscores, the explanation of the subscores and eventually a conclusive narrative for the combined categorical score.

Wind at Sea Case - Cost and Finance score: 1.1

The score is built up of the three sub factors related to one of the four categories of the Y-factor “cost and finance”. The Wind case has elements of high costs (2.0 as subscore), medium payback times (1.0 as subscore), and low difficulties with financing (0.3 as subscore).

The Energy production case is that of offshore windparks. The investment are very high, in the order of €2 million per Megawatt hour produced. So given the Dutch cabinets agreement and their target of adding 7 GW by 2030, this could be around €14 billion. The payback times are medium, but on average the contracts are designed to be around 10 years. The financing difficulties are low. Currently windpark exists, and subsidies are available. More interesting is that one of the tender applied without using subsidies. This was a first in the Netherlands.

The Cost and Finance of the wind case is characterized as medium, the investment costs can be very high, but there are reasonable businesses cases. One recent tender didn't even make use of subsidies.

Wind at Sea Case - Multi Actor score: 1.1

The score is built up of four factors related to multi actor category of the Y-factor. The Wind case has many actors involved (1.5 as subscore), of which few actors are seen as crucially dependent on (1.3 as subscore). The number of different types of actors in the Wind case is seen as medium (1.0 as subscore), and the responsibilities in the Wind case is seen as clear clear (1 as subscore).

The Wind case may have a lot of actors, mostly due to being in busy international waters, but also because of the coastal communities, but the actors important for the reaching the targets are few. A wind park tender can sometimes be won by single company. The installation sector is relatively small, but they have many employees, and they also act on the international wind turbine market. The process of allocation locations in the North Sea may involve many more stakeholders. However, the case in the Netherlands now is that it is not the issue. Moreover, the stakeholders seem quite organized, as there aren't many different types of actors. The actors are generally aligned and facing the same direction. Wind does not face strong opposition. The important actors, such as the grid operator find it the roles clear enough, the procedures and the new environmental law (not wind specific) helps clarify much as well, and ministries such as Min. EZK, Min. I&W and MinBZK are informed and facilitative enough.

The Multi Actor complexity of the Wind case is scored medium. While it could possibly affect many actors, there are only a few key actors. There aren't many different types of actors, as the coordination of stakeholders is good enough under current participation procedures. Roles are clear enough under the new environmental law and due to good alignment between the key governmental departments.

Wind at Sea Case - Physical Interdependencies score: 1.2

The score is built up of high physical embeddedness (subcore: 2), medium regular disturbances (subscore: 1.3) and medium technology uncertainty (subscore: 0.3).

The North Sea is a busy place for the Netherlands for wind parks, there are many navigation routes, pipelines, military functions and coastal communities. The North sea is also a harsh place for wind turbines, as regularly maintenance is needed. The maintenance is also quite expensive due to being at least 12 (nautical) miles of the shores. Wind turbines may disturb the wildlife through sound pollution and is dangerous for flying wildlife. The planned increase in wind energy production may imbalance the power grid on land. At times of construction, the drilling, and foundation may disturb the ocean floors wildlife. However, there are ways to keep the disturbance at a minimum. Current permit procedures provide enough room for such ecological adjustment. Last but not least, the wind turbines are not much dependent on technology anymore. The platforms, the turbines, the cables are proven tech, and are high in the technology level. New technologies for zero-maintenance are somewhat market ready, and the maintenance businesses are adapting. However, newer technologies such as “chemical at sea” and “power to gas” are still in R&D.

The physical interdependencies for the Wind Case is scored as medium overal. The wind case highly embedded into the physical environment as the offshore area is quite crowded with various economic and natural functions. Wind on sea may also disturb its natural environment,

and may increase the chance for imbalance for the power grid in general. The technologies for wind parks are mature and some new concepts, such as “chem on sea” are still in R&D.

Wind at Sea Case - Behavior score: 0.4

The score for behavior is built up of partially in the scope (subscore of 0.3), medium frequency of opportunities (subscore of 0) and high behavioral change (subscore of 1.0).

The wind sector in the Netherlands is generally well aware of the policy events, as the sector is accustomed to sector-wide energy accords.The past cabinets agreement is no surprise for many parties. The wind sector is quite international and the wind turbine installation sector is quite organized. The recent tenders for new windparks showed that not only the industry had experience, but also the government and the grid operator. Such opportunities are now a bit more frequent. Similar opportunities occurred in 2017, 2015 and 2008. Last but not least, the behavioral changes that are observed is relatively high compared to the other scores. The wind parks is characterized by the classic NIMBY problem, but is less apparent than wind turbines on land. 3D imaging are used for stakeholder meetings to let people comment on the actual differences to the visual pollution by the coastal communities. Sometimes some coastal communities will experience increased tourism. Another quantity or type of tourism flow could be a considerable change for a local region. For the many other households in the Netherlands, the new wind energy input will lead to no significant changes at all. However, for the grid operator, the large amount of planned wind energy offshore could increase the chances for imbalance on the regular power grid.

Wind on Sea has had a long public process before in the Netherlands, and therefore are within the scope of many parties. The case has been characterized by frequent opportunities, making the wind sector quite experienced, as well as the governments. Examples are recent wind on sea projects in 2017, 2015 and 2008. For the average civilians, the wind parks entail no behavioral change. The coastal communities might experience some changes, but the grid operator could experience more imbalance in the power grid.

Perspective analysis (Wind at Sea)

The perspective analysis is about the differences between the scores of the perspectives. A radar chart is used to help visualize the range of these differences and the general match between the perspectives. For the case, it is important where the main differences and similarities are, but it is also important to know that these results are all relative to each other. The focus of this analysis would be on each of the four category and find out about the largests and the smallest differences. A ranking relative to each other may be presented if interesting. Only the results of the categorical analysis and the radar chart tables will be used for analysis. If the radar chart reveals interesting points, this could be taken along too for the narrative.

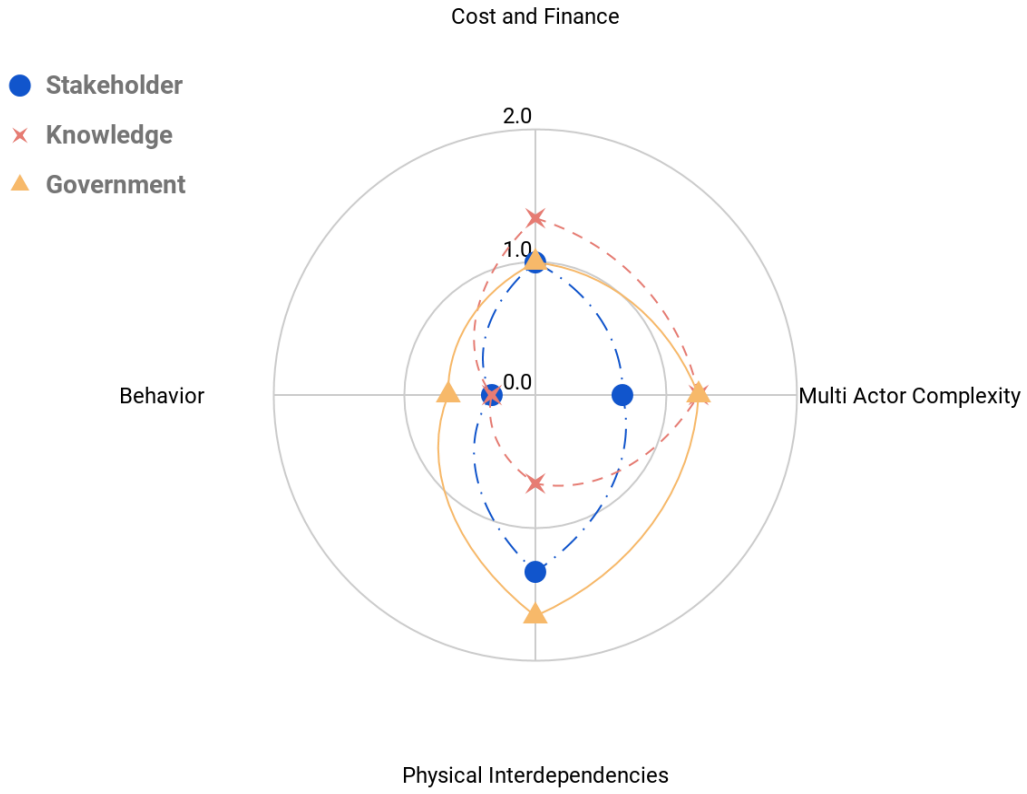

Figure 12 – Perspective analysis Wind

Description radar chart

For this wind energy case, one stakeholder, one knowledge organisation and one government are interviewed. A spider chart is used as a tool for the perspective analysis.

First, let's have a look at the inner circles, the outer circles and the overlaps. There is no apparent outer circle, the government perspective has the most outer points in the radar chart, and has the highest combined score 4.6. The knowledge perspective has the 2nd highest score (3.6) and the lowest score is right thereafter (3.3) for the stakeholder perspective. In the graph, it is completely unclear what the inner circles are. The stakeholder and the knowledge perspective are too similar to each other in this respect. However, the government perspective overlap with the knowledge perspective in the Multi Actor Complexity category. The government perspective also have overlaps in the category "Cost and Finance", but with the stakeholder perspective this time. The stakeholder and the knowledge perspective only overlap with each other in the behavior perspective.

Second, one can look at the differences and similarities by looking at the range of each category. The perspectives differ the most in the "Physical Interdependencies" category with a range of 1.0. Then the perspective differ the most in the "Multi Actor Complexity" with a range of 0.58. The perspectives differ the least in the remaining two categories of "Finance and Costs" and "Behavior". Looking more in-depth at the category with the biggest difference, the perspective agree that the physical embeddedness is high. Larger differences arose in the disturbance subfactor, between the knowledge perspective and the other two perspective. Then some differences in the proven tech subfactor only lead to a slightly bigger difference. The three perspective are quite similar in the three categories, with the government perspective generally sees more higher scores of the subfactors.

Concluding Narrative (Wind at Sea)

The concluding narrative has a twofold structure by combining the concluding remarks of the categorical and the perspective analysis. This allows for more nuances of the case specific categorical analysis shown before. The focus is on explaining the quantified subscores and the final Y-factor of the case.

The Y-factor for the wind energy case, based on a single case study on the Dutch "Wind op Zee" abatement option is 1.1 + 1.1 + 1.2 + 0.4 = 3.9. These subscores are respectively based on the category of cost & finance, multi actor complexity, physical interdependencies and behavior.

The Cost and Finance of the wind energy case is characterized as medium; the investment costs can be very high, but there are reasonable businesses cases. One recent tender didn't even make use of subsidies. The three perspectives - stakeholder, knowledge and government - differ the least in this category.

The Multi Actor complexity of the Wind case is scored medium. While it could possibly affect many actors, there are only a few key actors. There aren't many different types of actors, as the coordination of stakeholders is good enough under current participation procedures. Roles are clear enough under the new environmental law and due to good alignment between the key governmental departments. The perspective differ slightly here with each other, with no notable big differences in above statements.

The physical interdependencies for the Wind Case is scored as medium overall. The wind case highly embedded into the physical environment as the offshore area is quite crowded with various economic and natural functions. Wind on sea may also disturb its natural environment, and may increase the chance for imbalance for the power grid in general. The technologies for wind parks are mature and some new concepts, such as "chemical on sea" are still in R&D. The perspectives differ the most in this category. All generally agree on the high physical embeddedness, but differ most in how much it would disturb the surrounding and their daily operations, and differ slightly in how much uncertainty the wind case has to deal with.

Wind on Sea has had a long public process before in the Netherlands, and therefore are within the scope of many parties. The case has been characterized by frequent opportunities, making the wind sector quite experienced, as well as the governments. Examples are recent wind on sea projects in 2017, 2015 and 2008. For the average civilians, the wind parks entail no behavioral change. The coastal communities might experience some changes, but the grid operator could experience more imbalance in the power grid. The perspectives differ the least in this category, albeit sharing the same score with "cost and finance".

The applicability of Y-factor in the Wind case seems to be somewhat medium. One of the interviewees seems to have low understanding of the case. This concluded from the introduction, as well as the questioning round. This may be due to the practical interview difficulties experienced that day. However, for all interviewees, the categories of the Y-factor seems to be less apparent. While processing the data, the case seems to lack substance, the scores are generally low, and this may induce short answers. Two of the three interviewees showed signs of a constructive dialogue.

3.4 Case Forest

3.4.1 Case description (Forest)

Introduction

Scope: The "climate option" of afforestation of 100.000 hectare in the Netherlands. This should abate about 2.9 Mton of CO_2. The 100.000 hectare forest will have more than just CO_2 value, it will also have economic and social value, but also value for the nature.
Time: In 2030, 2.9 Mton is estimated to be abate by this afforestation option

Involved: The 100k ha is not one large piece of an area. Current forest is also not owned by one entity. Roughly speaking, the current forestry is owned by the government for 51% (such as the Ministry of Defense, Staatsbosbeheer, Rijksdiensten and municipalities), 33% is owned by private individuals, and 16% is owned by “nature” or environmental ngo’s or ENGO, for example “Natuurmonumenten”.
Recent media news: Actieplan Bos en Hout

Technical perspective
The Netherlands has around 365k ha forest. The climate option is to plant for 100k ha new forest. The ambition is not about one location, but at least 18 locations throughout the Netherlands (Actionplan Bos en Hout, 2016). Forests can be roughly broken down into two types: "multifunctional forests" and "non-timber forests". The latter type of forest is intended for experiencing the nature, and for biodiversity. It is not intended for cutting down trees and logging. “Multifunctional forests” may have different functions; this could be for the production of wood, but could also be for recreation, water management, buffer zone, among others. In the Netherlands pure timber forests do not exists, it is more of a label. Most of the Dutch wood, comes from cutting for the goal of maintenance. This is the same for pure non-timber forests. In the Netherlands, the term is used as a directing, some forest are more multifunctional than others. Afforestation in the Netherlands (of multifunctional forests), may be done on existing recreational terrains, on grassland, but could also be done on terrains whereas the ground is less suitable for agriculture or industry. Temporary locations may also be used for afforestation. It is likely that the exact forest project will be different for each location. The forest projects should be tailor-made for the local need and interests, and should contribute to the existing (public) function of the surrounding area. Innovative concepts for multifunctional forests are on the rise, such as combining living and forestry with Tiny Houses, trees along national highways, forests as natural barriers and water retention systems for water management, and forests as natural buffer zones for urban areas, and more. Currently, buying or leasing an area, is mostly based on a recreational business plan or from a maintenance plan. The Dutch wood industry has an estimated value of €15 to €20 billion euro. 97% of the revenue is from wood processing, only 3% of the value is from selling wood. The Dutch domestic wood demand is dependent on 90% import of wood.

Social perspective
The Dutch afforestation plan “Actieplan Bos en Hout”, is a joint initiative of forest owners, wood producers, paper and the paperboard industry, the pallet industry, construction companies, the recycling industry, environmental organisations and ngo’s for nature. The plan has created support for a public cause through covering both the stakeholders in both the public and private domain. However, it is not a plan from the central government. The action plan actually asks for financial support from the government, next to a contribution from signed parties. In order for a plan to be allocated in the government’s budget, a plan has to be at least evaluated at the PBL, the Dutch Planning Agency for Environmental Assessment. For a location to be assigned for afforestation a deliberation of economic value, nature, and social value has to be made. In principle there is no standard forest model for a location. Forestry are in principle also part of a larger regional development plan. A regional development plan envelops plans for other land-use functions, such as infrastructure, urban growth, farming, and other land use functions. Some areas are more suitable than others, for the 18 proposed locations, a more regional and specific assessment of the local context has to be made still. The proposed locations are not yet at all in implementation phase.

Figure 13 – The Dutch afforestation plan (Actionplan Bos en Hout, 2016)

3.4.2 Case analysis (Forest)

Keyword analysis

On the left of table 10, the scores are shown from the interviewees. The S stands for the stakeholder , the K is the knowledge organization, and G refers to a government perspective. The focus of the analysis is the set of thirteen subfactors, and trying to make sense of each subfactor through the comments given by all the interviewees.

Table 10 – Keyword analysis Forest

S	K	G	**The arguments and comments for the given subscores**
2	2	2	**Investments costs?** [0=absent, medium, 2=large] (2) Afforestation is expensive, around €3 billion. The majority of the costs are the land prices. De land prices can vary between 10k to 200k per hectare.
2	2	2	**Payback period?** [<5yr, 5-12yr, >20yr] (2) Forests have very long payback times. It could easily be more than 30+ years. It is uncommon to take into account payback times. Usually the maintenance is paid from the revenues over time.
2	1	2	**Difficulty in financing?** [none, medium, large] (1) there is enough political will. (2) Forest are someone's heritage, most forests are developed by landowners. Forestry have difficult business models if any.
1	1	1	**Number of actors?** [0=few, many, millions]

			(1) It is about 100k hectare, and at least 18 different projects. (It's an area larger than the Veluwe). Thousands are involved, not millions.
1	1	1	**How many dependencies on actors?** [0=none, few, 2=many] (1) 20 plus actors are seen as few.
0	2	2	**Number of types of actors?** [low, medium, many/large] (0) Mostly one opposing actor, the provinces are important. (2) long ongoing discussion of the "food vs nature", but also new discussions; the "climate vs the circular economy"; wood for sustainable furniture or letting them grow? And "climate vs energy"; wood as biomass or not?
1	1	1	**Clarity roles?** [clear, slightly, unclear] (1) A vision is still missing, despite current actions. Some roles do not have the necessary capacity yet. Current plan opened discussions of a second action plan.
2	1	1	**Physical embedded?** [0=none, medium, 2=strongly] (1) Embedded in the local land price (2) Embedded in area development process.
0	0	2	**Disturbance regular operation?** [none, medium, many] (0) new environmental law creates much order (2) too much forest may disturb biodiversity, both flora and fauna. May disturb other business cases in the proximity
1	0	0	**Technology uncertainty?** [proven, small, large] (0) Its about systems innovation; new toolbox for governments and stakeholders. (1) R&D into wood-as-plastic, "forest-pilots" for new methods for a better harvests and new products and services..
1	1	1	**Out of the scope?** [0=not, partially, 2=outside] (1) In the political spectrum. Public ceremonies with national politicians. However, not in recent coalition agreement.
2	2	2	**Frequency of opportunities?** [often, medium, rarely] (2) Forest intrinsically has a slow and long term outlook, with families leaving forest as legacy. Last public outcry around 20 years ago.
0	0	1	**Behavioral change?** [no, slightly, large] (0) old legacy, people generally welcome forest in neighborhood (1) perception of relationship between forest and wood need to change. Emotionally attracted, some people (near cities) forget that most forest is not part of the public space, and therefore have no "right" to a forest.

Categorical analysis (Afforestation)

The following analysis is about the discussion of the four categories of the Y-factor. The basis for discussion is the previous table of the 13 factors. The goal is not to show what arguments are similar or are different, but to summarize the category as a whole in the context of the case. The following will therefore first discuss the normalized score of the category, discuss the underlying scores and then summarize conclusively the category itself.

Afforestation case - Cost and Finance score: 1.9

The score is built up of high costs (2.0 as subscore), high payback times (2 as subscore), and medium to high difficulties with financing (1.5 as subscore).

The notion of high costs can be operationalized by around €3 billion euros as in capital investments, with an average of €30k per ha. This amounts to around €101 million euros per year for a project time of 30 years. Around 60% will come from public funding, the rest will be from the private sector themselves. The financing of forest is difficult due to long payback times. Current business models of forest mostly focus on just financing the operational expenditures of forests. Talking about break-even times, and earning back the investment is uncommon for the sector. Current forestry are developed through legacy and heritage structures.

Overall, the cost and finance category can be said to be high. The business case is seen as negative, if not non-existent. This is mainly because of the long payback time earning back the land prices. Most afforestation projects relied on heritage finance structures, this is difficult now. New business models are sought for more variations in financing structures.

Afforestation case - Multi Actor score: 1.2

The score is built up of four factors related to multi actor category of the Y-factor. The forestry case has few to many actors involved (1 as subscore), of which few actors are seen as important and being dependent on (1 as subscore). The number of different types of actors in the waste sector is seen as high (1.7 as subscore), and the responsibilities in the waste sector is seen as somewhat clear (1 as subscore).

In the forestry case, relatively many people are involved. It is about an area as one of the biggest National Park of the Netherlands (de Veluwe). Thousands people are involved, not millions. Around the 20+ actors are seen as crucial partners. The provinces are a crucial partner for all the afforestation sub-projects. Provinces have been excluded in an earlier process of making a plan for the forestry sector. The provinces are important due to their say in the current forestry stock. Province own directly and indirectly many acres of forestry. Provinces also oversee the regional development plans. The Action Plan in 2016, has opened up a lot of discussions, and some are still ongoing in 2018. Some older discussions were opened up again, but some new discussions emerges, and it seems that the stakeholders are converging towards a new state of status quo again. To be more specific, in the past, the “forestry vs agriculture” debate (nature or food security?) was important. More recently the climate vs renewable energy debate (wood as biomass?) has been important, now the climate vs circular economy debate (wood as co2 storage medium) is important. However, some stakeholders were excluded, and the updated and stronger vision and its underlying plan are yet to crystalized.

In conclusion, the forestry case is quite a case with a high amount of complex multi actor elements. The actual numbers of actors are over the thousands, but they seem to be organized and the amount of dependent actors are perceived as medium. In the past some crucial stakeholders were excluded, such as the province. The next plan will include these stakeholders and an updated and new vision will take over.

Afforestation case - Physical Interdependencies score: 0.9

The score is built up of medium physical embeddedness (subcore: 1.3), medium regular disturbances (subscore: 1) and medium technology uncertainty (subscore: 0.3).

Forest projects are quite affected by its physical environment. The land prices will influence when and how a forest project take place. The urban planning and regional planning may include or exclude forest projects for years to come. The actual implementation of forest projects may disturb the biodiversity of an area, in both flora and fauna. The surrounding businesses may also be affected. Maintenance is important, as it may affect the safety of hikers, pedestrians and road traffic. However, most of the times, the (new) Environmental law and procedure will help in avoiding most disturbance to the environment. Afforestation is no hard science nor much technological advanced. It is about system innovation with mostly the wood supply chain. However, some “forest pilots” exists that look for better yield technologies and new and more sustainable products from wood material.

In conclusion, creating 100k ha of new forests may depend much on ground prices and the surrounding existing natural and social context. Some new procedures exists to facilitate that process, but new forestry business models may demand other physical interdependencies. However, once planted, the maintenance should be straightforward. While the level of technology is low, some innovation regarding smart forestry management could modernise the legacy sector that is the forestry.

Afforestation case - Behavior score: 1.1

The score for behavior is built up of partially out of the scope (subscore of 1), seldom frequency of opportunities (subscore of 2) and low behavioral change (subscore of 0.3)

The "Actieplan Bos en Hout" has been in the political spectrum ever since it was published in 2016. The plan has political support, but it hasn't been explicitly stated in the recent coalition agreement of the new cabinet. Some other measures were mentioned, but it is not clear how it relates to the semi public private plan that is the "Actieplan". Forestry is a slow moving sector, with long lasting assets, from sometimes old families, and people who have been given a forest legacy from a previous generation. Some do find it interesting, because the sector didn't have this much commotion for over 20 years. The discussion that is ongoing is the dilemma between cutting down forest, or just letting them grow. For the goal of abating CO_2, storing wood in high quality furniture is the way to go. Not cutting forest might even hamper CO_2 storage, because trees grow slower that way. More awareness of such practices of the forest sector is needed. There isn't much behavioral change for actual forest projects. Generally, citizens are in favor of more nature. However, forestry may sometimes be perceived as a physical barrier, as in blocking the line of sight. Last but not least, an emotional attachment between the nature and human exists.

The forestry case scores medium in behavior. The forest industry is a slow moving one, but the climate discussion is one that the forest owners are aware of. The sector sees the need for more awareness among the citizens, and are opening up old, but also new discussions about the need and reasons for more and better forestry. It can be said that while the sector is a slow moving sector in terms of grabbing opportunities, but it seems to know intrinsically that sufficient and thoughtful attention should be given for a "change" of vision in the forestry sector.

Perspective analysis (Afforestation)

The perspective analysis is about the differences between the scores of the perspectives. A radar chart is used to help visualize the range of these differences and the general match between the perspectives. The focus of this analysis would be on each of the four category and find out about the largest and the smallest differences. A ranking relative to each other may be presented if interesting. Only the results of the categorical analysis and the radar chart tables will be used for analysis. If the radar chart reveals interesting points, this could be taken along too for the narrative.

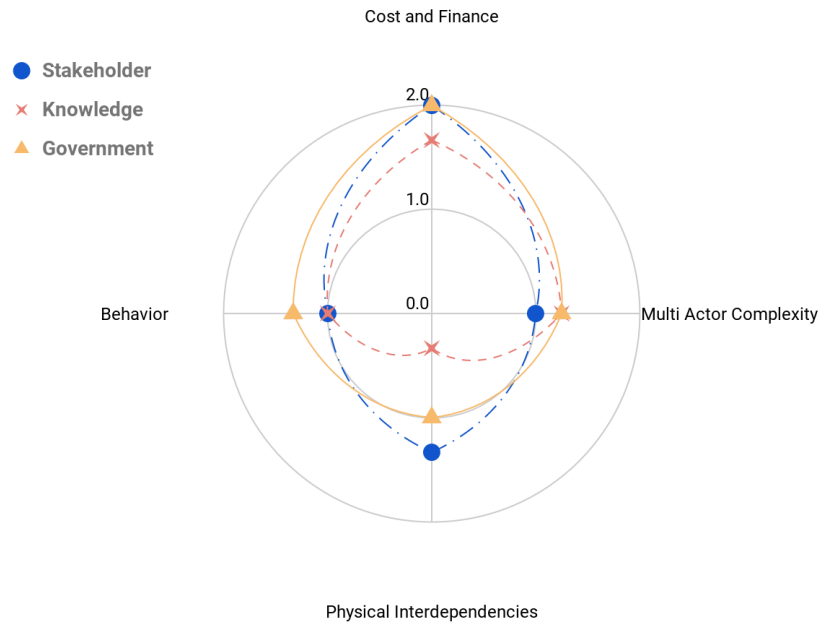

Figure 14 – Perspective analysis Forest

Three interviews has been done for the forestry case, one for each perspective; the stakeholder, knowledge and the government perspective.

First, the differences and similarities between the perspectives in a quantitative way. An indication of the relative range between the three interviewees can be given. The largest differences can be found in “physical interdependencies, the range is 1 (from 0.3 to 1.3). The second largest range is shared between the category of finance & costs and behavior, both have a range of 0.33. The most similar one is the multi actor complexity category. The three perspectives are very close to each other, with a range of 0.25 between the minimal score (1.0) and the maximal score (1.25). However, the score are very close to each other, when decreasing the decimal places, the range for all categories except for “physical interdependencies” are 0.3.

Second, one can look at the visuals for interesting observations. The knowledge organization is generally more low with his estimates, forming the inner circle. The stakeholder and the government seems to be generally higher in almost all category. As for the outer circle, the government perspective can be said to form that circle. None of the perspective scores less than 1 except for the knowledge organization in the physical interdependencies category. This can be seen by the only green cross in the inner circle indicated by the axis = 1.0.

Concluding narrative (Afforestation)

The concluding narrative has a twofold structure by combining the concluding remarks of the categorical and the perspective analysis. This allows for more nuances of the case specific categorical analysis shown before. The focus is on explaining the quantified subscores and the final Y-factor of the case.

Based on this forestry case, the Y-factor for afforestation is 1.9 for costs and finance, 1.2 for multi actor complexity, 0.9 for physical interdependencies and 1.1 for behavioral, resulting in a total score of 5.1 for the Y-factor.

The costs and finance for forestry is high. The business case is negative, if not non-existent. The forestry is characterized by very long payback time, more than 30 years. Past business models relied mostly on legacy and heritage finance structures. New business models exists, but are mostly in the design and discussion phase. The three perspective do not differ that much from each other. The three perspective mostly agree in the high capital and the long payback times, but differ slightly in the finance and the business models.

The multi actor complexity of afforestation is medium. The involved demographics can be said to be thousands if not more of land and terrain owners. Actors of afforestation appears to be fairly united in associations. The most recent action plans suggests that this is the case, and the actual dependent actors that are dependent are in the tends, and is considered low. The forestry has several new discussions with opponents, but also opened up old discussions. For the new afforestation plans, the clarity seems to clear, but has yet to crystallize fully, due to few missing actors. The three perspectives are the most similar in this category. The three perspective only slightly differ in assessing the number of different types of actors.

Given the characteristics of forestry, the physical interdependencies are medium. The location for forestry is mostly affected by the land prices. The highest prices are near urban areas. The forest projects might disturb others in the environment too. Too much forestry may actually disturb the biodiversity of an area. Other disturbance may also take place. However, a new environmental law and its procedures seems to help lower the disturbance to the social environment. Forestry is not characterized by high technology attributes, the dependencies from technology is low. The largest differences in perspectives can be found in this category for this case. The disturbance of regular operation is most accountable for this difference, some see current practices as fine, while some others sees much disturbance for the biodiversity and social economic environment.

The elements for behavioral for forestry is medium. The forestry case is a slow moving industry in terms of grabbing opportunities, but the sector appears to be aware of the recent climate discussion. The sector seems to be aware of the changing agenda, and reckon that better citizen awareness is needed. The last time such as commotion was happening was

already over 20 years ago. The three perspective do not differ much from each other, they only differ slightly whether people's behavior will change after a forest project.

The applicability of the Y-factor on the Forest case is high. The level of understanding is good, as experienced by good feedback by interviewees in the introduction. The collected data is also found useful for constructing case study. The interviewees had many insightful questions of their own, and the dialogues felt constructive. One interviewee even provided me with full stories of almost every questions.

3.5 Case Green Gas

3.5.1 Case description (Green Gas)

Introduction
Scope: Greenhouses are with the introduction of the CHP installation (Combined Heat and Power) (in Dutch: WKK: warmtekrachtkoppeling), more sustainable. However, CHP still uses natural and emit CO_2 among others. “Green gas” can be used for these CHP installations. Green gas is produced from renewable sources. How will the transition to “green WKK” look like?
Time: According to the past cabinet’s agreement, the target is set on 1 Mton CO_2 reduction by 2030. The ambition of Kas als Energiebron (KAE), a platform organisation of the horticulture and the Dutch government, is to have almost no CO_2 emission by 2050, while still being economically viable. Biogas to the greenhouses. Green gas is the upgraded version of biogas.
Involved: The Ministry of Economic Affairs and Climate, Ministry of Infrastructure and Environment, Ministry of Finance, LTO Nederland, LTO Glaskracht, Wageningen University and Research.
Recent developments: “Tightening CO_2 emission limit for the horticulture” (WUR, 2017). “Location green gas / CO_2 production”, (KAE, 2017). CO_2 from biomass quickscan (KAE, 2017).

Technical perspective
The CHP is essentially a small power plant that greenhouse owners can use to produce both heat and power (electricity). In the old situation, the electricity for the greenhouses comes from larger scale power plants, and the heat that would normally be produced, would be essentially seen as residual heat, as waste. Now with the CHP, both the heat from electricity production and the electricity can be used to the fullest in a greenhouse, as they need both: a warm climate and electricity for lighting. However, CHP uses gas, a possible future step would be to use “green gas”. Green gas is gas that is produced van renewable sources, such as from biomass. CHP can also be replaced by other renewable energy, such as geo-heating and wind farms, but for this case, the focus is on “green gas”. Some organization put “green gas” in the category of “bio-energy”. Green Gas is usually made from one method: fermentation. This is a process of anaerobe process and produces methane. In the next process, the upgrade installation will upgrade the methane to the quality levels of normal natural gas, and can be sold through the normal gas network. Gas fermentation also exists, but is less used. Syngas is short for synthetic gas, and can be made from electricity. The technology is still in development, but in the Netherlands this also falls under Green Gas.

Social perspective
In the horticulture, farmers usually have a CHP. The energy efficiency is the main driver for most farmers. The energy efficiency is also the main driver for the Dutch governmental to promote the use of CHP in the horticulture and agriculture in 2003 and 2006 with subsidies. Other users of CHP are for example hospitals and factories. As biomass and natural gas are the main inputs for the CHP, a purchase process is needed for supplying the CHP. Biomass can come from a variety of producers, such as the local waste factory, or the green waste

trader. Biomass can be dry or wet. The forest ranger may sometimes act as a green waste trader, as the forest regularly needs maintenance. The LTO is a Dutch branch organization for horticulture, and aims to serve his thousands of members with their knowledge and expertise, for example for implementing and installing such a CHP. A national platform with the name “Kas als Energiebron” is specifically launched to bring forward multiple concepts of “greenhouses as energy sources”. In this concept, the farmer will be able to generate power instead of just consuming it by means bio-energy, but also geothermal energy and solar energy.

3.5.2 Case analysis (Green Gas)

Keyword analysis

On the left of table 11, the scores are given by the interviewees. The S stands for the stakeholder , the K is the knowledge organization, and G refers to a government perspective. The focus of the analysis is the set of thirteen subfactors, and trying to make sense of each subfactor through the comments given by all the interviewees.

Table 11 – Keyword analysis Green Gas

S	K1	K2	G1	G2	**Main motivation for the score?**
2	2	2	2	2	**Investments costs?** [0=absent, medium, 2=large] (2) from 200k to 800k euro. Dependent on power output, but also whether it is a biogas or a biogas to green gas installation
1	2	1	1	1	**Payback period?** [<5yr, 5-12yr, >20yr] (1) Usually designed for 10 years, due to maintenance sensitive installations. Sometimes designed for the 12 years of the subsidies. (2) Gas fermentation is still too expensive, there is no payback time here.
2	2	1	2	1	**Difficulty in financing?** [none, medium, large] (1) most installations are not viable without subsidies. Business case is not cheaper with green gas. (2) subsidies are irregular and variations in business cases are limited. Not suited for small farmers
1	1	1	1	1	**Number of actors?** [0=few, many, millions] (1) suppliers of biomassa (farmers and special biomass producers), users and transporters (pipelines and trucks). Not in the millions. Recently 118 tenders awarded for 98 biogas installations and even 20 green gas installations.
1	2	1	2	2	**How many dependencies on actors?** [0=none, few, 2=many] (1) especially cattle farmers, "roadside grass", and the municipalities. (2) manure, but also banks, milk-industry, forestry and other biomass sellers. It is sometimes unclear where and who the biomass sellers are.
2	0	1	1	1	**Number of types of actors?** [low, medium, many/large] (0) the (wider) anti-gas movement and the CE-movement (1) newer role for the gas network, the transport regulation stakeholders, uncertified biomass suppliers. (2) the local, provincial and national permits needed for the different sources of biomass.
1	1	2	0	1	**Clarity roles?** [clear, slightly, unclear] (0) in principle, gas network operator need to be aligned and on board for the upcoming biogas supply (1) Clear enough to cut down on fossil fuel use, but unclarity due to many types of biogas farmers. (2) unclarity wider role of gas in the energy mix (bio-based economy lost its traction).
1	2	1	1	0	**Physical embedded?** [0=none, medium, 2=strongly] (0) in principle everywhere, but generally in East-NL. (1) there may be some biomass hotspots; such as water treatment plants and food factories. (2) dependent on the gas

					(pipe)network. May be too full, sales of bio-energy depends on seasonal variations.
1	2	0	x	1	**Disturbance regular operation?** [none, medium, many] (0) own terrain (1) newer roads for biomass trucks, new quality processes (2) basically a new company, might disturb your own company. Need a biomass + gas buffer (storage) place
2	0	0	1	1	**Technology uncertainty?** [proven, small, large] (0) used for years, green gas somewhat later but still on the marke, but still not competitive. (1) very low adoption by the market. (2) syngas, the next step for green gas is still underdeveloped.
1	0	1	0	0	**Out of the scope?** [0=not, partially, 2=outside] (0) not for the farmers and horticulture. Close through large branche organisations, new platform innovation platform, experience with sector wide covenants (1) not specific enough in cabinet's agreement, not all farmers are looking forward to it.
1	0	x	1	0	**Frequency of opportunities?** [often, medium, rarely] (0) greenhouses act fast on such opportunities (example from 2004-to 2010) often initiate themselves (1) quite entrepreneurial, but mostly triggered by manure-overload.
2	1	2	2	2	**Behavioral change?** [no, slightly, large] (1) greenhouses shouldn't experience any large changes (2) the ones with the bio-installation will experience societal pressure (from neighbors due to smell, horizon, increased transport movements), change of work (daily monitoring, periodic expert checks ups, upfront training, additional quality assurance.) Sometimes just not part of the farmer's passion.

Categorical analysis (Green gas)

The focus of the analysis is the set of four categories. The method is to try to make sense of each category by condensing it into first one quantified subfactor and substantiate it with help of the keyword analysis. Each category is discussed in three: the subscores, the explanation of the subscores and eventually a conclusive narrative for the combined categorical score.

Green gas Case - Cost and Finance score: 1.6

The score is built up of the three sub factors related to one of the four categories of the Y-factor "cost and finance". The green gas case has elements of high costs (2.0 as subscore), medium to high payback times (1.2 as subscore), and high difficulties with financing (1.6 as subscore).

The capital investment for the bio-installations are high from 200k to 800k if they have an upgrade component for biogas to green gas. The bio-installations are usually designed for 10 years due to maintenance sensitive equipments. Sometimes they are designed specifically for the maximum of the 12 year of the energy (SDE) subsidy. Green gas is more expensive than natural gas, without a subsidy on its exploitation (on the basis of a cubic gas), the bio-installation is not possible. This is mostly due to the high operational costs, due to costly biomass per kilogram. Costs for biomass can vary from 1/3 to 1/2 of the costs. The gas fermentation module for green costs is often too expensive. The finance is therefore very dependent on subsidies. There are few variations of business cases for green gas. Financing is also not possible for smaller farmers

The cost and financial aspect of this case is characterized by large capex, but mostly by the high opex, they can be as high as half of the total costs. Bio-installations, and the module to green gas is without subsidies not a positive business case. Financing is much dependent on subsidies, and financing is often only within reach for the larger farmers.

Green gas Case - Multi Actor score: 1.2

The score is built up of four factors related to multi actor category of the Y-factor. The green gas case has many actors involved (1.0 as subscore), of which again many actors are seen as crucially dependent on (1.6 as subscore). The number of different types of actors in the housing case is seen as high (1.0 as subscore), and the responsibilities in the waste case is seen as slightly clear (1.0 as subscore).

The green gas case has moderate amount of actors. Generally there are two main actors, the biomass supplier and the biomass consumer or the biogas and green gas consumer/producer. Recent tender in the Netherlands have granted around 98 biogas and 20 green gas installations. These two actors dependency on other actors is considered quite high, as the biomass supplier is dependent on cattle farmers (for manure), certain (food) factories, forestry, and also "roadside grass". Biomass can come from various places, and sometimes it is unclear where biomass comes from exactly. The biomass consumer is dependent on banks, the milk industry, a local green gas hub. The amount of different types of actors in this case is average. Some examples of different types of actors are the anti-gas movement, and the CE-movement, because sometimes it is quite unclear where the biomass comes from (sometimes from unsustainable sources). An illustrative metaphor is the phrase "green electrons, but also green molecules", referring to the renewables vs bio-mass discussion. The transport type of actor, such as the gas grid, may also value the transport integrity more than risking inputs from decentralized points in the gas grid. The roles in the bio and green gas case is moderately clear. In principle, the transport or the grid operator just need to facilitate the link between the biomass seller and buyer, but there is unclarity in how the sector should exactly deal with "unsustainable" biomass. A more general notion relates to the role of the bio-based economy in the wider energy mix and sustainable energy economy. The sector has seen some bio-based roadmaps in the recent years, but some (actor) unclarity remains.

The green gas is scored medium in the Multi Actor complexity, there are moderate amount of actors, but the actors experience quite some high dependencies with other actors. For example, the dependency on the fragmented local biomass stakeholders and suppliers. The number of different types of actors are moderate, so are the roles for the green gas. Some uncertainties were dealt with in the past green gas roadmaps, but some uncertainties remain. For example the role of the "green molecules".

Green gas Case - Physical Interdependencies score: 0.9

The score is built up of medium physical embeddedness (subcore: 1.0), medium regular disturbances (subscore: 1.0) and medium technology uncertainty (subscore: 0.8).

The physical embeddedness of the green gas is medium, in principle a biogas installation can be placed everywhere, but it is best to place it around "biomass hotspots". Certain factories (such as water treatment or food factories) may create such hotspots, and a pipeline network may also contribute to such hotspots. In the Netherlands, the sale of both biomass and green gas may be subjected to seasonal variations. For example, the normal gas pipeline could be too full due to regionally low daily usage of gas in summertimes (due to the pipeline pressure). The disturbance a biogas installation would cause to its surroundings would be moderate, there is little environmental damage, but there will be increased road traffic. Additionally, space will be needed for a biomass buffer and biogas or green gas storage tank. The dependencies on technology is medium. The reason for this is that biogas has been used for decades and green gas for years, but still not competitive compared to normal gas. The technology of green gas installations is somewhat newer, and is characterized as having very low market adoption in the Netherlands. New methods to create green gas, sometimes called syngas, are still in development, and may decrease the dependency on technology.

The green gas case is characterized with moderate physical interdependencies. Bio gas installations may depend moderately on biomass hotspots and the pipeline network. The installations may disturb the neighbors, and may cause increased road traffic and additional space for the farmer for a buffer and storage. The technology uncertainty is somewhat medium, as the technology is developed and market ready, but could be less uncertain if syngas would

be researched more.

Green gas Case - Behavior score: 0.9

The score for behavior is built up of partially in the scope (subscore of 0.4), medium frequency of opportunities (subscore of 0.5) and high behavioral change (subscore of 1.8).

The green gas case is within the scope of the horticulture as a sector. Through the branche associations, the sector is quite connected. Moreover, the new platform for new energy initiatives (KAE) is also helping to increase the expert knowledge and awareness. However, individual farmers might still be unaware, and not all farmers are looking forward to the newly set ambitions. The frequency of opportunities is often to average, many farmers, especially the greenhouses are quick with business opportunities compared to the agricultural farmers due to smaller, but more intense assets. However, the sector may sometimes get too much CO_2 and energy opportunities. Some opportunities are triggered by a manure-excess, such as with the cattle farmers. While the scores are low for the green gas case, the behavioral change is scored as very high. For the greenhouses, few behavioral changes are present. Their current way of working stays within their boundaries of changes. For other farmers, the bio-installation could mean switching to a more machine operated way of working; such as engineering maintenance, monitoring, periodic check ups and upfront training, and more. For some it could be like opening a second business; an energy company. This may not align with the intrinsic values of the farmer, as this might not be every' s farmers passion. With new bio-installation, the farmer will also have more interactions with their neighbors due to increased transport movements, smell and new visuals (as the installations can be quite large).

The green gas case is characterized by entrepreneurial actors, and are quite connected and informed. Large behavioral elements can be found for the maintaining and the operating of the installations. Depending on the exact new bio-installations, the project could be a real undertaking and would feel for some to be opening a new local energy company, which would bring along a whole new set of changes.

Perspective analysis (Green gas)

The perspective analysis is about the differences between the scores of the perspectives. A radar chart is used to help visualize the range of these differences and the general match between the perspectives. For the case, it is important where the main differences and similarities are, but it is also important to know that these results are all relative to each other. The focus of this analysis would be on each of the four category and find out about the largest and the smallest differences. A ranking relative to each other may be presented if interesting. Only the results of the categorical analysis and the radar chart tables will be used for analysis. If the radar chart reveals interesting points, this could be taken along too for the narrative.

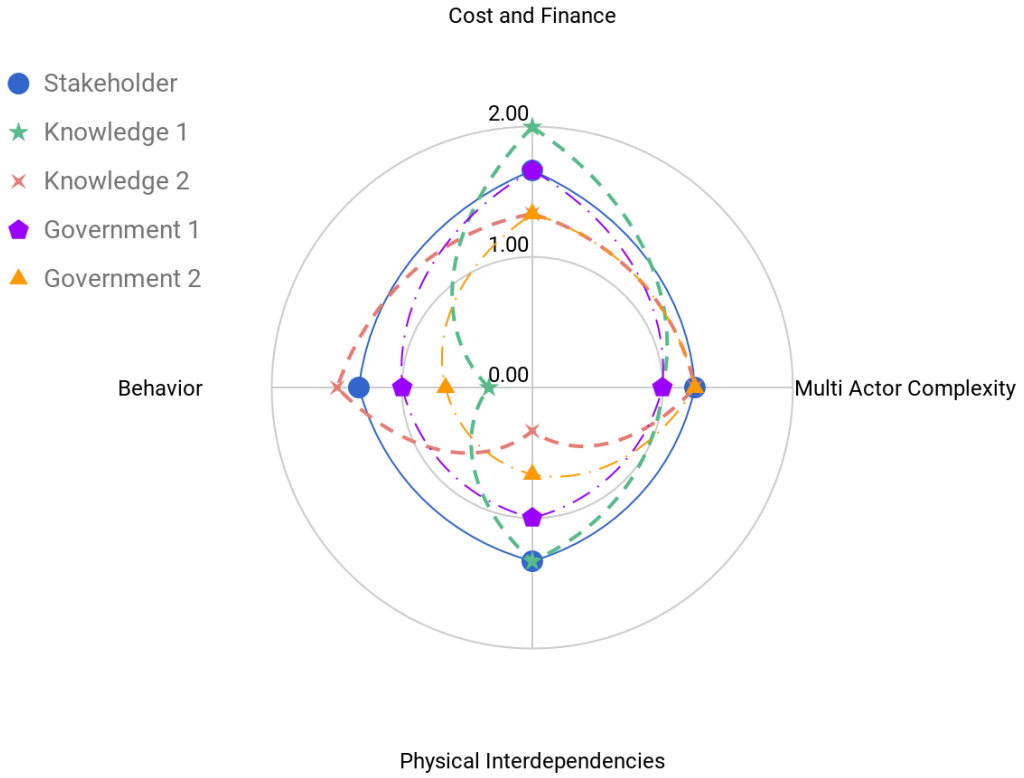

Figure 15 – Perspective analysis Green Gas

Description radar chart

In the agriculture case study, one stakeholder, two knowledge organizations and two government are interviewed. The radar chart is used as an analysis tool for discussing the different perspectives. At first glance, the more crowded radar chart might be less insightful compared to the radar charts of the other cases. However, it can still be useful.

First, one can look at the inner circles, the outer circles and overlaps. In this radar chart, there are two interviewees for two perspectives. The two interviewees of the same perspective should be close to each other in relation to the other perspectives. However, this is not the case here, for example in “behavior” (the green and red dashed lines) and for physical interdependencies. The two interviewees for the government perspective do come closely more than the two interviewees from the knowledge perspective. The yellow triangle and the purple pentagon are next to each other in every category. It can be said that for this case, the Knowledge perspective differ more than the two Government perspective. The Stakeholder (the blue line) can be marked as the out circle, its score is the highest (5.6). The follow up high scores are: Knowledge 1 and Government 1 (shared 4.7), Knowledge 2 (4.4) and Government 2 (3.9). The scores are relatively close to each other, and this can be seen from the overview created by the radar chart too. There are few overlaps in lines, except for the green Knowledge 1 perspective in Behavior. This perspective sees very few behavioral elements.

Second, one can discuss the difference of the perspective by the range of each category. The largest range is that of the Behavioral category (1.2). In this case, the two Knowledge interviewees differs the greatest from each other. In this category there is also a general range between all the interviewees, with no overlaps. The category with the shortest range is that of the Multi Actor complexity, here the perspectives only differ from each other for 0.25 at a maximum. The range of Physical Interdependencies and Cost and Finance are 1.0 and 0.7 respectively. It is eye-catching that the two knowledge interviewee differ from each other the most in actually all four categories. In the radar chart, one can see that they are always at the two ends, sometimes overlapping with other interviewees, but always at the two ends.

Concluding narrative analysis (Green gas)
The concluding narrative has a twofold structure by combining the concluding remarks of the categorical and the perspective analysis. This allows for more nuances of the case specific categorical analysis shown before. The focus is on explaining the quantified subscores and the final Y-factor of the case. The Y-factor for the Green Gas case is 1.6 + 1.2 + 0.9 + 0.9 = 4.6. The scores are respectively Finance and Costs, Multi Actor Complexity, Physical Interdependencies and Behavior.

The Cost and Financial aspect of this case is characterized by large capex, but mostly by the high opex, purchasing biomass can take up to half of the total costs. Bio-installations, and the module to green gas is without subsidies not a positive business case. Financing is much dependent on subsidies, and financing is often only within reach for the larger farmers. The perspectives differ relatively little in this category.

In the Multi Actor complexity, the green gas is scored medium. The case has moderate amount of actors, but the actors in the case experience quite high dependencies from other actors. For example, the dependency on the fragmented local biomass stakeholders and suppliers. The number of different types of actors are moderate, so are the roles for the green gas. Some uncertainties were dealt with in the past with roadmaps about the role of green gas in the bio-based economy. However, actors reckon that some uncertainties remain, such as its role in the climate economy. An illustrative metaphor is the phrase “green electrons, but also green molecules”, referring to the renewables vs bio-mass debate. The perspectives in this case differ the least with each other among the other four categories.

For Physical Interdependencies, the green case has characterized the category with a medium score. Bio / green gas installations may depend moderately on biomass hotspots and the pipeline network. The installations may disturb the neighbors, and may cause increased road traffic and additional space for the farmer for a buffer and storage. However, it is only experience as medium. The technology uncertainty is also scored medium, as the technology for the case is developed and market ready. However, the case would be less uncertain if syngas would be researched more. The perspectives differ in this category somewhat, the knowledge perspective differ the most with each other.

The Behavioral category is scored medium in the green gas case. The case is characterized by entrepreneurial actors, and they are quite connected and informed. Large behavioral elements can be found, which was the main driver for the higher score. The commented behavioral changes are for the farmers maintaining and operating the installations. Depending on the exact new bio-installations, the project could be a real undertaking and would feel for some to be like starting a new local energy company, which could bring along a whole new set of changes. The perspectives in this category differ the most with each other. However, the subfactors of this category is somewhat skewed. All perspective generally agree that the case is within the scope of most actors, and that they grab such opportunities quite frequently as they are characterized as quite entrepreneurial. However, all would agree that having an bio-installation would still cause a lot of behavioral change.

The applicability of the Y-factor on the Green Gas case is somewhat high. The usefulness for case is good, but in the introduction the Y-factor seems to be require more information. This could be due to the more specific technology of the case. However, the dialogues felt constructive and information between two side felt sufficient exchanged.

3.6 Case Waste

3.6.1 Case description (Waste)

Introduction

Scope: 2 Mton CO_2 reduction to the AVI's, the waste incineration installations according to the "Regeerakkoord". The idea is that the waste incineration industry would come to a set of measures to capture the CO_2 from the incineration chimneys. The specific institutional or policy measure is to increase the tariffs for "incineration and waste dumping". Another policy measure is to widen the scope of the SDE+ for carbon capture and storage for AVI's specifically. There are about 13 incineration plants.
Time: The targets are meant for 2030 (Regeerakkoord). The waste sector itself also has ambitions for decreasing the overall garbage per inhabitant. The target is to 30kg per inhabitant per year in 2025.
Involved: The Vereniging van Afvalbedrijven, branche association for recycling, Ministry of I&M, Ministry of Finance, the ILT (the inspection authority), large industry parties, such as Veolia, Remondis, Alba, Suez, FCC, etc.
Recent developments: More collaboration with municipality and the "diftar system" (Rabobank article), basically a system that rewards citizens' good behavior (e.g. less municipal tax for households with less waste).

Technical perspective

The Netherlands has around 13 waste to energy or in Dutch: “Afvalverbrandingsinstallaties” (AVI). In theory, the ambition of reducing 2 Mton CO_2 emissions by 2030 can be accomplished by capturing all the CO_2 of only two AVI’s. Albeit these AVI’s have to be the biggest two. To capture CO_2 at AVI, an intermediate transport and storage medium is needed. On average, AVI may emit 6000 ton CO_2 per day. It has been established that storing CO_2 underground near urban is socially unacceptable. To transport and store CO_2, additional costs may incur compared to a continuous CO_2 pipeline connection from the AVI to a storage medium. All 13 AVI’s are built near urban areas. A carbon capturing installation, sometimes called a carbon filter, consists generally of 4 parts or 4 (filtering) process. The first process cools down the exhaust fumes from the chimneys of the AVI. The second process is to “boil out” the fumes. The third process is another cooling down process, and last but not least, the last process involved compressing the gas into a liquid state and stored in tankers/trucks. The carbon capturing installation can take up a large space, it could mean a spatial expansion of 50%. For the construction of the capturing installation, the construction of a temporary factory is common. For any spatial expansion, a permit is required. Some AVI’s in the Netherlands have already gotten some of their expansion permit approved. Changes to the current structure of the AVI might be needed, such as increasing the height of the chimneys and additional installations for the waste water. Currently CO_2 from waste plants need to go through new quality requirements. While the capturing process is well understood technically, the CO_2 in the supply chain could be subjected to additional quality requirements.

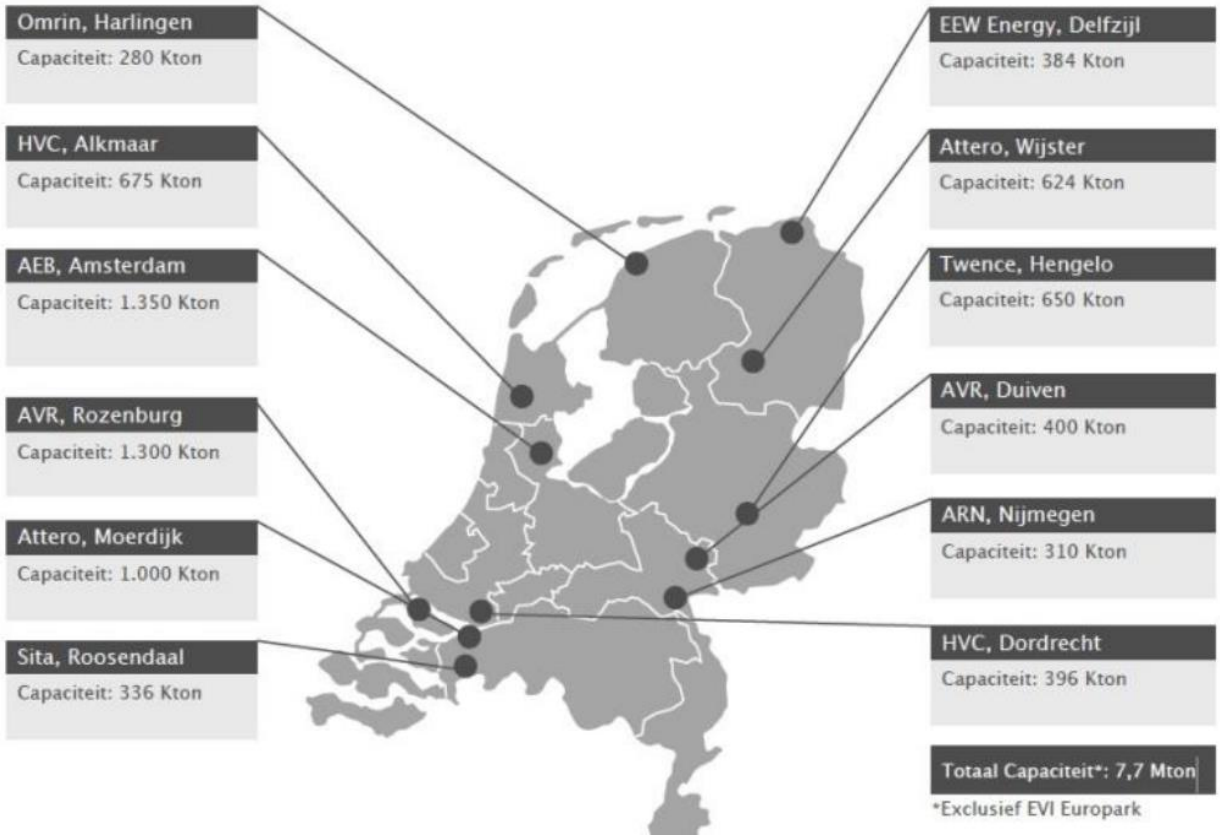

Figure 16 – Waste Incineration Plants in NL (van Klink & van der Vusse, 2015)

Social perspective

In the Netherlands, there are around 13 AVI's and they are owned by 9 companies. Some companies own 2 plants. About the half of the companies are actually semi-public organizations, owned by municipalities. Some AVI's are large and may have several types of product or service than just burning waste. They may sell the bottom-ash, they may sell heat for urban areas, of steam for industries. For a national CO2 and waste incineration policy, there may only be a few waste representatives needed. The AVI's have generally good relationships with the surroundings stakeholders, such as the municipalities, as they have historically collaborated much with each other. Moreover, waste projects have generally had good consultation processes with the public.

The construction of a carbon capture installation is mostly a Dutch project, while the installation components can be an international undertaking. It is expected that the installation sector will experience a learning curve, in the Netherlands, the carbon capture installation are new. In the Netherlands there is no AVI with a carbon capture installation of this size. There is one other smaller carbon capture system, but they are capture in powder form and in small quantities. The AVI's themselves are also relatively new with such carbon capture installations and they also need to undergo a learning curve. The Dutch waste sector is also characterized by a certain degree of international competition, waste from foreign country are bought and transported to keep a steady business flow and operational efficiency. The most common importer is the UK, because they have relatively few waste incineration plants themselves. If processing waste becomes more expensive, for example if due to the carbon capture installations, then this may influence the position of the AVI in the Netherlands internationally. If waste incineration plants can be marked as being more green, as a unique selling point, then this may not affect the competition position as much. Internationally, in the area of carbon capture, the waste plants in Norway can be seen as good examples. AVI's may not only want to capture carbon, but also want to have parties helping them store it, or utilize it. For example the horticulture may be possible customers of the captured CO2.

3.6.2 Case analysis (Waste)

Keyword analysis

The keyword analysis shows the most important arguments and comments behind each score. Table 12 shows the table for the waste case.

Table 12 – Keyword analysis Waste case

S1	S2	K	G	EN keywords
2	2	2	2	**Investments costs?** [0=absent, medium, 2=large] Millions of euros in CAPEX. OPEX range from 30 to 300 euros per ton CO_2 produced.
2	2	1	1	**Payback period?** [<5yr, 5-12yr, >20yr] (1) 10 years for capex, (2) in theory infinite due to large opex.
2	1	1	0	**Difficulty in financing?** [none, medium, large] (0) financing is easy because co-owner by municipalities. Good guarantees due to a public good. (1) not that difficult due to traditional business with predictable cash flows. (2) hurdles due to difficulties multiple subsidies.
0	1	1	0	**Number of actors?** [0=few, many, millions] (0) 13 avi's in the Netherlands, owned by about 9 companies Small installation sector,, around the 100-200 consultants/companies. (1) Estimate future CCU market: hundreds to thousands of CO_2 customers.
2	2	1	1	**How many dependencies on actors?** [0=none, few, 2=many] (1) few, only the municipalities and the local environmental agencies. (2) high dependency from the installation sector (some companies abroad).
1	2	0	0	**Number of types of actors?** [low, medium, many/large] (0) quite closed professional network. (1) many different types exists, but addressed in good formalized public consultation processes. (2) many types of actors from the material industry.
0	0	2	1	**Clarity roles?** [clear, slightly, unclear] (0) roles good relationships with citizens, municipalities. Builds on past ambitions of environmental goals (soil, air and sound pollutions). (1) high level members from national government (2) absent of central high-level board from industry for CO_2
1	x	0	1	**Physical embedded?** [0=none, medium, 2=strongly] 0 = can be built anywhere. Easier if near CO_2 customers, such as the horticulture . 1 = Even more easier if near existing CO_2 pipelines.
1	2	0	1	**Disturbance regular operation?** [none, medium, many] 0 = no significant disturbance if done at maintenance times. 1 = needs additional CO_2 buffer space projects. 2 = needs redesigning existing structure due different fumes and wastewater.
2	2	x	0	**Technology uncertainty?** [proven, small, large] 0 = TRL of six and seven. 2 = Never done before in the NL, need upscaling and supply chain innovation and CO_2 product research
1	1	1	0	**Out of the scope?** [0=not, partially, 2=outside] 0 = large and active branche association with comprehensive knowledge distribution. 1 = aware of own high CO_2 output, but not the agenda. Significant numbers of laggards exists
0	0	2	0	**Frequency of opportunities?** [often, medium, rarely] 0 = Creating core-business transcending every 5-10 years. 2 = Reactive to opportunities. Last big change was 20 years ago.

1	0	0	1	**Behavioral change?** [no, slightly, large] 0 = no changes for end-users such as the horticulture customers and citizens. 1= Change in working with a new product for the food industry in the context of food safety, such as the truckers in the supply chain.

Categorical analysis (Waste)

The following discusses the four categories on the basis of the previous keyword analysis table. The goal is not to show what arguments interviewees had given for a particularly score, but to summarize the category as a whole in the context of this case. The following will therefore first discuss the normalized or the average score of the category and then put the total underlying subscores in perspective.

Waste Case - Cost and Finance score: 1.5

The score is built up of the three factors related to one of the four categories of the Y-factor "cost and finance". The waste sector case has elements of high costs (2.0 as subscore), medium to high payback times (1.5 as subscore), and medium difficulties with financing (1.0 as subscore).

The notion of high costs can be operationalized by several millions (€1 - 10) as in capital investments, depending on the exact the installations. However, high costs is mostly mentioned due to large operational costs. These vary from from tens to €300 per ton CO_2 produced. To put it into the case perspective, the operational costs is said to be high, because the energy required for the CO_2 capturing process can use about one third of the energy produced by the waste to energy plant itself. The high operational costs, makes it hard (to impossible) to have a short payback time, given the market prices of CO_2. The difficulty in financing is considered medium, because of unclarity about the subsidy landscape. However, the waste-to-energy plants have relatively predictable business cases, and good relationships with their municipalities, and may not be restricted to the private equity market only. Therefore, the difficulty of financing aspect is considered medium.

Overall, the cost and finance category can be said to be high. The business case is seen as negative, and this is mainly due to the high operational expenditures (OPEX). Filtering CO_2 from the exhaust fumes can costs about one third of the energy produced from the plant itself. The financing part is less of an issue, as traditionally AVI's have good cash flows, and are co-owned by municipalities. While AVI's are somewhat experienced with subsidies, they nevertheless face hurdles and some extra costs.

Waste Case - Multi Actor score: 0.9

The score is built up of four factors related to multi actor category of the Y-factor. The waste sector case has few to many actors involved (0.5 as subscore), of which medium to many actors are seen as important and being dependent on (1.5 as subscore). The number of different types of actors in the waste sector is seen as low to medium (0.75 as subscore), and the responsibilities in the waste sector is seen as clear to slightly clear (0.75 as subscore).

In the waste case, there seems to be the few actors that represent the world of the AVI's. There are 9 operators of AVI's, but there are around 13 AVI's in total. In the case of implementing carbon capture installations, contractors and business partners are mentioned, but the estimates are but few hundreds, and not in the thousands, or millions. A new market (CO_2 demand from the horticulture) is being mentioned too here that is part of the actors, that could increase the actors in absolute numbers. For these reasons, the first subfactor is labeled as few (0.5). The actors that the case is dependent on are municipalities and environmental organisations. AVI's consider these as quite some actors that they are dependent on (1.5). This is because around half of the AVI's in the Netherlands are co-owned by municipalities. For some AVI's, the regional environmental authority and inspection agency is also important. However, other AVI's found their respective environmental agency less important. The reasons given

were that they were relatively small and had less experience with core-business transcending affairs. The AVI's do not have much opposing actors (0.75). This is largely explained by that the AVI's have generally positive image. Some might see it as a dirty job, but nevertheless they will comment on that it is necessary and environmental cleaner than just dumping waste on a landfill. Few opposition exists against AVI in general, but this is also true for the carbon installation. Respondents confirm this by recent public consultation processes, where there hasn't been any large complaints. In advancing the whole AVI sector closer to the emission target, the roles seems to be clear enough (0.75). The current provincial procedure for public consultation is clear enough. However, some note that the sector might benefit from a high level table of 15-20 people in the context of the recent CO_2 targets. Some note that a CO_2 roadmap could exists for the sector, but are not sure.

In conclusion, the AVI case does not show much elements of a complex multi actor environment. There are few actors in the sense of absolute numbers, and dependent actors are seen as being low as well. Generally, the AVI's are only dependent on municipalities and environmental agencies. Furthermore, the actors in the sector seem to be well aware of each other, and AVI's seems to experience not much different types of (conflicting) actors. In its whole, the actor constellation is somewhat facing the same direction, although some centralized group of high level representatives (for the new CO_2 targets) could be useful, although not seen as a prerequisite for reducing CO_2.

Waste Case - Physical Interdependencies score: 1.0

The score is built up of medium physical embeddedness (subcore: 1), medium regular disturbances (subscore: 1) and medium technology uncertainty (subscore: 1.3).

AVI's are generally quite flexible in their geographical location. They need a large area and prefer to stay somewhat close to urban areas, and if possible to industry. This make them more cost-effective, as in principle they only need to be connected to (or embedded in) the road infrastructure. The carbon capture system however, are seen to be more embedded in a carbon market. Being in close proximity to horticulture, will make it more cost-effective, and thus more easier for AVI's to build carbon capture installations. Implementing such carbon installations should not significantly affect the daily operations of itself or others in the environment. However, changes to the chimneys for the exhaust fumes might be needed. Additional installations might be required for the wastewater too. This is to comply to air and soil quality environmental regulation. The technology uncertainty is considered as high because in the Netherlands, such technologies have never been applied before to AVI's. The carbon capture and storage technology itself is maturing (TRL 6-7), but high technology uncertainty is felt, as innovation in upscaling and supply chain innovation is called upon for. In terms of carbon capture and utilization technologies, its related product innovations, and its product qualities, the technology uncertainty is still seen as high.

In conclusion, AVI's are medium in their physical interdependencies. For carbon capture and storage systems, the AVI's highly prefer to be around potential CO_2 consumers. They could act as storage buffers later. The construction of ccs does not disturb any operation, but it is very likely that adjustment to the whole plants is needed due to environmental regulation. The uncertainty in the core technology for storage is low, but as it is never applied in Dutch AVI's before, some uncertainty is experienced. In CO_2 applications, there are still some technology uncertainties.

Waste Case - Behavior score: 0.6

The score for behavior is built up of partially to not out of the scope (subscore of 0.75), high frequency of opportunities (subscore of 0.5) and low behavioral change (subscore of 0.5)

The waste sector is usually aware of the broader policy context through the branche association. The branche association might even have provided text for the CO_2 emission targets to the recent governmental coalition agreement. The diffusion of knowledge seems to

be good throughout the network. The frequency of business opportunities seems to be responsive. Historically, AVI's have been "making a living from policy changes". In the past decade, business opportunities with a positive prospect of 3 to 5 years are observed as common. As for more larger changes, such as from selling electricity only, to selling steam, heat, but also ashes, some AVI's have fail to react, but some AVI's did indeed. Some AVI's are said to be quite entrepreneurial. From a project-level perspective, the contractors for building the installations needs to learn and grow. This is also true for the project partners.

For AVI's the behavioral changes are not much of a topic. The end-users of waste are not involved, and the current CO_2 consumers are already aware due to similar CO_2 producers. The waste sector only experience a generic behavioral change as they have never sold a product before for the food applications. The employees only have experience with selling heat, steam and ashes.

Perspective analysis (Waste)

The perspective analysis is about the differences between the scores of the perspectives. A radar chart is used to help visualize the range of these differences and the general match between the perspectives. For the case, it is important where the main differences and similarities are, but it is also important to know that these results are all relative to each other. The focus of this analysis would be on each of the four category and find out about the largest and the smallest differences. A ranking relative to each other may be presented if interesting. Only the results of the categorical analysis and the radar chart will be used for analysis. If the radar chart reveals interesting points, this could be taken along too for the narrative.

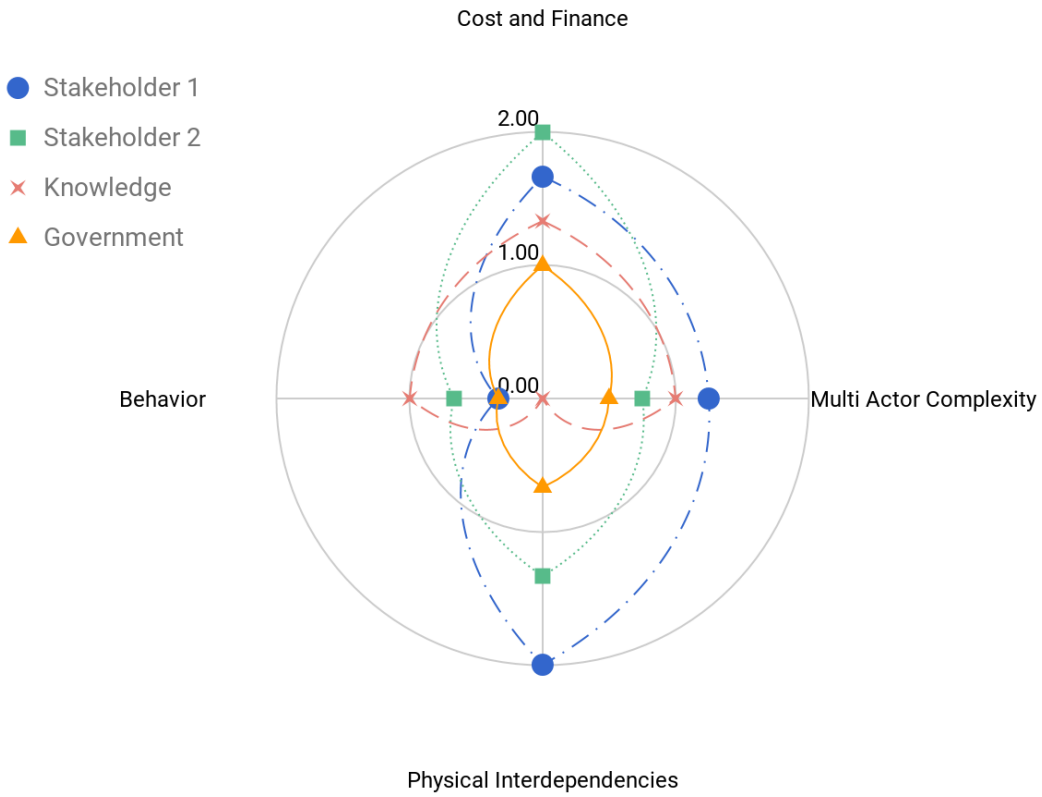

Figure 17 – Perspective analysis Waste

In the waste case, two stakeholders are interviewed, one knowledge organization and one government. A spider chart is used as a tool for analysis.

First, the differences and similarities between the perspectives in a quantitative way. An indication of the relative range between the four interviewees can be given. The largest differences can be found in “physical interdependencies” between the four interviewees, with a range of 2. Then followed by finance & costs with a range of 1 (from 1 to 2), and then multi actor complexity with a range of 0.8 (from 0.5 to 1.3). The most similar one is “behavior” with a range of 0.7. This means that for this case, the four interviewee are most similar to each other in this category. One can also see that the stakeholders have higher combined scores, i.e. with scores of 5.3 and 4.8, as opposed to 3.3 (knowledge) and 2.5 (government).

Second, one can look at what stands out visually. As expected for interviewees of the same group, the two stakeholders (red square and blue dot) are more close with each other than the two other perspectives. This can be exemplified by the categories, finance and costs, and physical interdependencies. In these two categories, the two stakeholder also stand out, with the two highest scores. The government stands out as being the inner circle of the chart, in almost all categories, except for physical interdependencies. The knowledge perspective has the highest score for behavior, and the lowest score of physical interdependencies.

Concluding narrative (Waste)

The concluding narrative has a twofold structure by combining the concluding remarks of the categorical and the perspective analysis. This allows for more nuances of the case specific categorical analysis shown before. The focus is on explaining the quantified subscores and the final Y-factor of the case.

Based on this single case of the waste sector, the Y-factor of the waste climate measure is 2 for high costs and finance + 1 for medium multi actor complexity + 1 for medium physical interdependencies and 1 for medium behavior, resulting in a score of 5 for the Y-factor.

The cost and finance category is high. The business case is seen as negative, and this is mainly due to the high operational expenditures (OPEX). Filtering CO_2 from the exhaust fumes can costs about one of the third of the energy produced from the plant itself. The financing part is less of an issue, as traditionally AVI's have good cash flows, are co-owned by municipalities and may be eligible for subsidies. Based on the qualitative interviews of the three perspectives, the costs and finance score range from medium to high. The three perspective differ the most in the financing aspect only, some reckon that subsidies actually makes financing more difficult.

For the score of multi actor complexity, the AVI case shows some elements of a complex multi actor environment. Firstly, the case shows that it has few actors in the sense of absolute numbers and the actors in the sector seem to be well aware of each other. It can be said that the whole actor constellation of the sector is somewhat facing the same direction. The 13 AVI's are mostly dependent on municipalities and environmental agencies, but also on the carbon installation sector supply and the CO_2 customers demand. Some AVI's do not seem to experience much different types of (conflicting) actors, the environmental procedures provides enough clarity. However, some reckon that a more visible centralized group of high level representatives (specifically for the new CO_2 targets) would be useful. The perspectives differ somewhat in the scores here too. The scores range from 0.5 to 1.3. The stakeholder perspective sees quite some (conflicting) types of actors, but enough clarity in roles, while both the knowledge and government feel almost the opposite way; not much conflicting types of actors and to not enough clarity for the sector.

The physical interdependencies of AVI’s are medium. For the carbon capture installations, the AVI's are somewhat embedded in geospatial way, all the first carbon installations are at AVI’s that are in close proximity to a horticulture hotspot, where there is CO_2 demand. While the construction of the carbon capture installation would not disturb any daily operation of anyone in the direct environment, it is likely that structural adjustment to the plant itself is needed, such as taller chimneys and additional waste water treatments. The technology for carbon capture is maturing, the TRL estimates are 6 -7, and some AVI uses open source technologies, so the technology dependency is low. However, the technology is never applied in Dutch AVI's before. The AVI’s do notice technology uncertainty in the CO_2

market, such as CO_2 as construction materials. This is why they prefer to be near a high CO_2 demand. Of all the categories of the Y-factor, the scores of the perspectives differ the greatest here, they range from 0 to 2. The knowledge and the government perspective seem to see few actual disturbance and low technology uncertainty, while the stakeholders see the exact opposite; high disturbance and high technology uncertainty. Reflection is needed in why these differ that much.

For AVI's the behavioral changes are not much of a topic. The AVI's and its branch association of the sector seems to be well aware, and seems to have provided text for the last cabinet's accord too. The AVI as a collection of employees that form a company, seems to have experience with a variety of business opportunities. However, the sector has never sold a product before that needs to meet food-like certification and qualities. Citizens and other end-users are not much in the picture, as no habit change is required from them unlike the recycle-movement that started tens of years ago and still going strong now. The behavioral category is the least diverse in its perspectives, it has a range of 0.7. If it wasn't for the following score the range would be twice as small. The knowledge perspective, reckon that waste sector is quite reactive and slow towards opportunities. While some perspectives see large opportunities for the sector every few years, the knowledge perspective reckon that the only recent big opportunity that changed the industry was over 20 years ago.
The applicability of the Y-factor on the Waste case is high. The introduction of the interviews received good feedback, and the collected data has provided with enough insight to construct the case study. The dialogues with interviewees felt constructive overall.

3.7 Interim conclusion

In this chapter, six case studies of six abatement options are presented by means of the Y-factor. Several interviews are carried in a semi-structured format per case study, and for each case study, the case description is presented and four case analyses are conducted. This is done in order to answer the second research question, as proposed in chapter 1:

RQ1: What is the applicability of the Y-factor on a variety of abatement options?

To answer this research question, first the observation can be made that the Y-factor is useful in designing the interviews. As seen from section 3.1 to 3.6, the insights retrieved from the six case studies are substantive, but the applicability might be different. For this, several criteria were formulated in the beginning of chapter three to assess the applicability. The arguments for these criteria were also explained, and it has been chosen to assess the applicability through these three criteria:

- Level of understanding in practice (of the research and the asked factors/questions)
- Usefulness for creating a case study (retrieved what was needed for the case study?)
- Level of constructive dialogue (resulted in an in-depth and meaningful conversation?)

Table 13 – Applicability of the single case studies

Case	Level of understanding	Usefulness case study	Constructive dialogue
CCU	Yes	Somewhat	Yes
Housing	Yes	Yes	Yes
Wind	Somewhat	Somewhat	Somewhat
Forest	Yes	Yes	Yes
Green Gas	Somewhat	Yes	Yes
Waste	Yes	Yes	Yes

The assessment of the applicability for the six cases can be found in table 13. Overall, in all of the six case studies were the level of understanding was high. Most interviewees

understood the various subfactors of the Y-factor. There was no significant disagreement between the factors in the cases. No case stood out particularly in the case of (mis)understanding. Most interviewees were engaged and showed a good level of understanding. However, the questions were not straightforward and follow-up questions were in abundance. I have concluded that for the Wind case, the level of understanding was somewhat lower. Some questions were explicitly commented on the relevancy. In the Green Gas case, the level of understanding was scored somewhat lower too, as the introduction of each interview seems to last longer than the other five. This could be due to the more specialized domain of biogas.

The usefulness of the Y-factor for the six case studies is generally high. The majority of the scores could be filled in by the interviewees themselves, or by my interpretation of their answers. For the Housing case, the Y-factor has been received very well. One of the interviewee recognized the majority of the factors. For the Forest case, the interviewees were also familiar with the concepts. Only the technology question was not very useful for the Forest case. Looking at the missing data in the framework, the distribution thereof seems to be quite random for every case, and thus acceptable. For the Wind case, the Y-factor might be less useful, as some comments were made about the payback time subfactor being irrelevant. The Behavioral category in the Wind case was commented to be hard to fill in, as some answer seems to relate to the other categories, such as the Multi Actor category. For example, the answer about the wider societal energy demand, and that stakeholders are generally satisfied in stakeholder meetings. A special remark need to be made for the CCU case. Two interviews were excluded in the thesis, both were for the CCU case. They were both too incomplete to be included in the analyses. One interview was from a knowledge organization, and another interview was from a stakeholder. The first interviewee had questions about the invitations and also the interview questions. The first interview was stopped in between the interview and thus the interview was discarded. The reason given was that the interviewee did not agree with the research framework. More specific questions were deemed necessary for the interviewee to accept such a process of data gathering. For the second interviewee, the interviewee was hesitant at the start, and wanted know the specific questions. The general feedback from this interviewee is that the issue is still relatively fresh and recent and that such questions shouldn't be asked, at least not in such a way.

For the third and last criterion, almost all cases are assessed as having a constructive dialogue. The Wind case is marked with a lower constructive dialogue. One of the interviews conducted felt like as if the interview was more like a scripted and written survey. In this interview, I felt like little information is exchanged. However, the other two interviews in the Wind case did not have this issue. Most interviewees commented on the relevance and genuinely asked about the result of the study at the end of the interviews. For me this was a sign that the interviewees was at least to some degree engaged and in a forward thinking mode. This also lead me believe that a constructive dialogue is made.

Overall, the Y-factor seems to be understood, and proved to be useful in constructing case study. The applicability of the Y-factor is high, on the basis of these six case studies, the highest applicability are the Housing, Forest and the Waste case. The lowest is the Wind case

4. Multiple Case Study

"When we have multiple conflicting ends that are incommensurable, the solution is not to choose among them and/or impose some metric that makes them commensurable, but rather to find a way that all the ends can be realized simultaneously."
Richardson, 1997

In chapter three, the Y-factor is seen to have a certain applicability when it comes to conducting case studies for abatement options. Six individual case studies were carried out and analyzed individually. However, how do these six cases compare to each other? In this chapter, several comparison exercises are performed using the Y-factor. In the spirit of "show, don't tell", this is done to answer to the third research question:

- RQ3: How can CO_2 abatement options be compared by means of the Y-factor?

First of all, comparing abatement options may be perceived as comparing apples to oranges. How one compares them depends on their point of view, or in other words their perspective. For example, it could depend on a healthy point of view, (e.g. which one has more nutrients?), a situational context point of view (which one is better for on the go?), or another point of view. What is the goal of the comparison. In this thesis, the transition perspective is adopted, and used the Y-factor as a framework to construct case studies.

To answer RQ3, 4 comparisons are carried out. These are:

1. Observations of the six cases
    a. Quantitative statistics of the 13 scores. What insights stands out?
    b. Qualitative descriptions or narratives of the four categories. What are the similarities and differences?
2. Comparison with theories
    a. What patterns can be observed in the four narratives? The assumption is that the questions only serve as starting points. What are interesting (patterns of) observations? How do they relate to the scores of the Y-factor?
    b. How do these patterns compare with theories? What are the similarities and differences?

3. Perspective analysis: what are the similarities and differences? No particular expectations of the three perspectives are given.
4. Comparison with the MACC. How to compare the y-factor with the MACC? What are the similarities, and what are the differences?

To answer these four subquestions, chapter three is used as inputs for the multiple case analysis.

4.1 Observations of the 6 cases

4.1.1 Quantitative statistics of the 6 cases

From a quantitative view on the six cases, a table with descriptive statistics is used. Table 14 below shows all 21 interviews and their scores of the six cases. Each column represents one interviewee, they are labelled as S, K or G in the top row, and the abbreviation stands for stakeholder, knowledge organization or government respectively. The rows form the 13 subfactors of the Y-factor. The scores range from 0 to 2, and some are marked with x. The x-mark indicate that on the basis of the interview, the score for that subfactor is inconclusive. Other descriptive statistics for each row and columns are not shown, such as the standard deviation, and the average. As the goal is not to conduct statistical analysis, but to represent the underlying data.

The high level overview of the six cases shows a few interesting observations. First, the inconclusive x-marks only represent 8 of the 13*21 scores, this is 0.03%. The x-marks appears to be scattered throughout the six cases at random. Although one category Physical Interdependencies (PHI) appears to have relatively more x-marks. Second, the red 2-scores seems to cover the top-left side of the table more than the bottom-right. The top represents the Cost and Finance (C&F) category, and the bottom represents the Behavioral (Beh) category. Third, the 1-score seems to be dominant in table 14, and the 0-scores the least. The exact frequencies for 0, 1 and 2 are respectively 54, 109 and 102. Fourth, the variations between each category for each case, so the variations within the (4x6=) 24 boxes, is high. The 0, 1 and 2 scores can be found in most boxes. However, 4 boxes (C&F CCU, Forest, and Green Gas, and Phi CCU) only have 1 and 2 scores. For one box (C&F CCU), almost all scores are marked as 2. Lastly, a row represents a subfactor, and a column represents one interviewee. Most rows have 0, 1 and 2 scores. Again, about 3 rows have only 1 and 2 scores. Most columns, or in other words, most interviewees, give out all three scores. However, about 2 columns have no single 0-score.

On the basis of these five observations, the scores seems to show quite variations, but also gives enough room for some special variations, such as sometimes no 0-scores at all. Most categories, boxes, rows and columns have relatively high scores. This can be linked back to the low frequencies of 0 in observation three.

This brief quantitative overview of all cases, shows that there might be some underlying patterns for the scores, and that there are enough similarities and differences underlying the scores. This makes it more likely that the answers representing the scores are sensible, however further in-depth comparison is needed.

Table 14 – Overview of the scores of the 21 interviews and six cases

	Interviewee perspectives	K	K	G	S	K	G	S	K	G	S	K	G	S	K	K	G	G	S	S	K	G
	Case name	CCU			Housing			Wind on Sea			Forest			Green gas					Waste			
Cost and Finance	**Investments costs?** [0=absent, 1=medium, 2=large]	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Payback period? [0 = <5yr, 1 = 5-12yr, 2 = >20yr]	2	2	2	1	1	2	1	1	x	2	2	2	1	2	1	1	1	2	2	1	1
	Financieringsdrempels? [0=none, 1=medium, 2=large]	1	2	2	2	1	0	0	1	0	2	1	2	2	2	1	2	1	1	2	1	0
Multi Actor	**Number of actors?** [0=few, 1=many, 2=millions]	1	0	2	2	2	2	x	1	2	1	1	1	1	1	1	1	1	1	0	1	0
	Dependency on actors? [0=none, 1=few, 2=many]	1	1	2	2	2	2	1	2	1	1	1	1	1	2	1	2	2	2	2	1	1
	Number of types of actoren? [0=low, 1=medium, 2=many]	1	x	2	2	2	1	1	1	1	0	2	2	2	0	1	1	1	2	1	0	0
	Clarity roles? [0=clear, 1=slightly, 2=unclear]	1	1	1	0	2	1	0	1	1	1	1	1	1	1	2	0	1	0	0	2	1
Physical Interdepe	**Physical embedded?** [0=none, 1=medium, 2=strong]	2	2	1	2	2	2	2	2	2	2	1	1	1	2	1	1	0	x	1	0	1
	Disturbance regular operation? [0=none, 1=medium, 2=many]	2	1	x	2	2	0	2	0	2	0	0	2	1	2	0	x	1	2	1	0	1
	Technology uncertainty? [0=proven, 1=small, 2=large]	1	1	1	1	1	1	0	0	1	1	0	0	2	0	0	1	1	2	2	x	0
Behavior	**Out of the scope?** [0=not, 1=partially, 2=outside]	0	1	1	2	0	1	1	0	0	1	1	1	1	0	1	0	0	1	1	1	0
	Frequency opportunities? [0=often, 1=medium, 2=rarely]	1	1	2	2	1	0	0	0	0	2	2	2	1	0	x	1	0	0	0	2	0
	Behavioral change? [0=no, 1=slightly, 2=large]	0	2	2	2	2	2	0	1	2	0	0	1	2	1	2	2	2	0	1	0	1

4.1.2 Qualitative observations of the 6 cases

For a qualitative comparison of the six cases, observations are done at the level of the four categories instead. First, the combined score of each categories for the six cases are compiled in table 15. The table now show 6x4=24 scores, the demarcation of score is now similar to the aforementioned “24 boxes” in observation four in section 4.1.1. Second, comparison is done for the six cases in their categorical scores, four sub paragraphs will therefore follow, four categorical narratives are constructed. The data used are the data from the keyword analysis, the categorical analysis and the concluding narrative of each single case. In other words, the six single studies will be used as an input for explaining the each categorical score of the six cases. The key analysis should help us find details about the scores, and the categorical analysis and the concluding narrative of each case should help us reflect on the case relative to the other five cases. This helped us look beyond the single case itself, and helped us focus on the comments and explanation to the right subfactor as much as possible.

Table 15 – Overview categorical scores of the six cases

	CCU	Housing	Wind	Forest	Green Gas	Waste
C&F	2 (1.9)	1 (1.3)	1 (1.1)	2 (1.9)	2 (1.6)	2 (1.5)
MA	1 (1.2)	2 (1.7)	1 (1.1)	1 (1.1)	1 (1.2)	1 (0.9)
PHI	1 (1.4)	1 (1.4)	1 (1.2)	1 (0.8)	1 (0.9)	1 (1.0)
Beh	1 (1.1)	1 (1.3)	0 (0.4)	1 (1.1)	1 (0.9)	1 (0.6)

Cost & Finance of the six cases

The score for the CCU is 1.9. The current plan is still in a conceptual phase. Subsidies have been awarded for mostly preliminary research, and for now many types of subsidies might be needed, e.g. subsidies are being sought on the national but also on the EU-level. Work is needed for creating viable business cases. The capex (capital expenditures) is hundreds of million depending on the actual design, and the opex (operating expenses) can be as high as €150 per

ton CO2, but has a large range to down to tens of euro. However, even with the lowest opex, given the CO2 prizes, the investments can never be earned back. This makes financing difficult.
The score for the Housing is 1.3. The Housing case has developed market viable arrangement for financing CO_2 refurbishments, the EPC, the "Energy Performance Contract". In short, this is an arrangement where upfront investments by households can be avoided through the promised future energy savings of the new refurbishment. The business case has become more viable with such market arrangements for some houses. However, despite the innovative contract, the housing case is far from being saturated, and is in need for more and better scaled up business cases. Current capex range from several thousands to as high as 80k. The opex is low, but the margins are low too. Therefore the related return of investment (roi) can be long, around 10 years. Often such roi is considered too long and therefore not accepted. Lastly, many mortgages are "underwater", causing extra difficulties for financing arrangements.
The score for the Wind at Sea case is 1.1. Now (spring 2018) the first subsidy-free offshore windpark is a reality in the Netherlands. Subsidies for wind has been around for at least 10 years. The costs are around €2 million per megawatt, the allocated wind tenders accounts for 7 GW, which could make up for €14 billion. Wind turbines at sea are designed for around 10 years. Some experts are already worrying about too much gigawatts being on the grid on land and one could say market saturation is the next problem for the wind energy production. For some wind parks, some subsidies might still be needed.
The score for the Forest is 1.9. Forestry is expensive and the current plan is still in the conceptual phase. The cost of the current plan is €3 billion for 30 years, shared between private and the government, 40% and 60% respectively. Current costs for forestry is largely for maintenance, and the maintenance is covered by the sales from the "maintenance wood". Forestry is mostly heritage, and developed by landowners or volunteers. Forestry have few, if any at all positive business cases.
The score for the Green Gas is 1.6. For almost all farmers, the upgrade from a biogas installation to green gas installation is a negative business case. The capex range from 200k of an average biogas installation to 800k for a green gas installation. The opex for producing one cubic meter of green gas is high and still cannot compete with the normal gas price. The payback time would be too long without an opex subsidy. The high opex is mostly due to the high costs for biomass, and they can account up to 2/3 of the opex. The finance is therefore largely dependent on subsidies. Recently, 20 green gas and 98 biogas installation tenders were awarded. For the tenders, a national exploitation subsidy (the SDE+ subsidy) is considered to be a crucial part.
The score for the Waste case is 1.5. The AVI's are generally good businesses, and due to their assets and relative stable cash flows, making investment is generally not an issue, even if a carbon capture installation may costs millions of euros. Moreover, some AVI have a co-ownership with municipalities, and therefore have a larger societal responsibility and budget. However, the opex is more of an issue, they range from 30 to 300 euros per ton CO2. The CO2 installations may use up to one third of the AVI's produced energy. Nevertheless, such prices are too high for the market, and most AVI's cannot create a positive business case for carbon capture under normal market conditions. Some AVI's have started some experiments. Sometimes subsidies makes financing more difficult, and large notable subsidies from the central government has yet to be identified.

In the Cost & Finance category, 'business case' seems to be a recurring remark. In these remarks, a business case either exist or not, referring to positive or negative business case. In three cases (CCU, Forest, Green Gas), interviewees explicitly mention that a business case only exist, if there is 'subsidy'. Different types of subsidies are mentioned, such as from different sources such as from European, national or regional governments (CCU and Forest), the mechanism of the subsidy, such as geared towards opex or capex (Green Gas/CCU and Forestry), and whether the subsidy is for a (preliminary or feasibility) study (CCU / Forest), or a project with actual assets (Green Gas). The level of government, may belong to the MA category. Sometimes, the business case has other financial arrangements, such as for the

Waste case (shared ownership with municipalities) and the Housing case (the EPC). The uncertainty and risk of the business case is said to be lower and more spread out, which makes the business case more viable. In the Wind case, market parties have built a business case without subsidy, a first in the offshore wind park business. In the Wind case, the experts are now talking about market saturation instead.

Multi Actor of the six cases

CCU is scored 1.2. A multi actor team is involved, and consists of the Dutch two biggest cities and two biggest provinces, and engineering companies and several large horticulture partners. EU-level organizations are involved too, but mostly from a knowledge and tender perspective. Even the ministry is quite involved along with industry. Thousands are involved, but no masterplan exists. However, a high level "climate table" at a ministerial level has just formed. Moreover, there is a large knowledge community, but the business community, the buyers and sellers, still need to grow and develop in this new CO_2 as a natural resource market. There is a certain dependency with this business community as an actor, but also the European subsidies organizations. Citizens and environmental organizations consider CCS, but also CCU controversial, as a climate solution (Carbon Capture and Storage vs Carbon Capture and Utilization, portrait as merrily short term and blocking solutions).
Housing is scored 1.7. Millions of house owners, and too many type of housing and owners too. There is much dependency on each household, but also on the installation sector, as the sector is fragmented and not always readily available due to wider economic competitive conditions. For housing corporations, at least hundreds of multidisciplinary teams are needed to reach the goals set forth for the housing corporations. The roles in the housing sector are slightly unclear, as there are different thoughts about the alignment with the installation sector, and there is a general sentiment that climate goals should not precede affordable housing goals.
Wind at Sea is scored 1.1. Public is generally aligned and facing the same (wind) direction. Several roadmaps over the course of years. Many types of stakeholders exists, but public consultation guidelines and procedures seem to deliberate stakeholders values good enough. Small professional installation network, but with activity in the national and international market, and in quite large numbers when it comes to actual employees.
Forest is scored 1.1. Some actors are not aligned (provinces) with the recent large sector wide plan formed by a multi actor team. Also some important actors are not involved yet, these are the developers of very specific forestry and the high end wood quality industry. First afforestation plan since at least 20 years ago. Somewhat low clarity about the role of forest and wood in the public debate of "nature vs food", and "renewables and wood".
Green Gas is scored 1.2. Moderate amount of actors. Generally there are two actors in the value chain, the biomass supplier (cattle farmers, factories, green waste traders, etc.) and the biogas or green gas consumer/producer (horticulture, and other farmers). Recently a large multinational together with a group of farmers won a total of 118 biogas / green gas tender. A multi actor platform exists, with active support from ministries However, platform is very focused on horticulture related bio-energy, and not bio-energy in general. Competition with other energy initiatives. One roadmap few years ago, but provided insufficient clarity for the sector on the role of "bio-energy in the wider energy mix" discussion and "sustainable biomass" discussion.
Waste is scored 0.9. Small network of AVI's, but strong national business network, with the help of an active branch association. AVI's get support from municipalities, and have generally good relationships with the neighborhood and its supply chain. The AVI actors are generally facing the same direction. A small team of 10-15 representative from the waste sector would suffice for carbon capture installations, but is said to be missing.

In the Multi Actor category, several recurring remarks are observed. For the question of role clarity, often mentioned are roadmaps, route maps or masterplans, or the lack of such. (CCU, Wind, Forest, Green Gas). Multi actor teams, multi actor platforms, or multidisciplinary teams are mentioned in the CCU, Housing, Forest, Green Gas case and the Waste case. For the Housing case, very specific data were giving to the numbers of multi actor teams, there ought

to be at least 300 of such teams with each around 10 people. For the Waste case, one sector representative team of 10 to 15 individuals was said to be lacking. Another observation, in the question of 'type of actors', are the answers of a 'public debate' (CCU), controversy (CCU), 'discussion' (Green Gas), a 'sentiment' (Housing) and 'the public generally facing the same direction' (Wind, Waste), the latter implying few or no public debates. Last, but not least, the value/supply chain (Green Gas and the Waste case) or the business (engineering/installation) network is often mentioned (CCU, Housing, Wind). In the Forest case, the developers of forestry and the wood industry is mentioned, which could be referred to as the partners in the value chain.

Physical Interdependencies of the six cases

CCU is scored 1.4. CO_2 pipelines are embedded around clusters of horticulture, and existing pipelines, but also on the locations of suppliers and producers. New installations for the last miles of pipelines could disturb environment and the business operation itself, even at maintenance times. Technology is market ready, but larger scaling up demonstrations are needed for the market. Some carbon technology (for storage) are still in R&D phase. The Technology Readiness Level (TRL) is used to indicate the technology uncertainty, in this case a TRL of 3 to 6 is mentioned.

Housing is scored 1.4. Houses are embedded in the larger neighborhood / municipal development context. But refurbishment depend mostly on the age and characteristics of the building. Many small issues could occur, for example issues related to general renovations of the building or building complex, such as structural integrity of the walls and facades. Disturbs the daily and personal space of inhabitants, some need to relocate. Technology is proven, and is market ready, but very low market adoption (0.5%), innovations for cheaper costs price of the installations are needed.

Wind at Sea is scored 1.2. Wind turbines development offshore is subjected to many rules. The offshore marine space is crowded, as shown sometimes visually in a map with many layers. However, currently the space allocation for wind parks is sufficient. Moreover, new marine and land power cable infrastructure follow wind parks locations, and not the other way around. Disturbance of wind parks to other systems is low, but significant for the marine ecosystem directly around the turbine. The technology readiness level is market ready and high. New types of maintenance innovations are on the rise. New windpark technologies needed.

Forest is scored 0.8. Afforestation projects are embedded in its local environment. For example, they are also part of the larger municipal urban planning systems and the general land use management at the regional level, and sometimes at the national level, especially for areas around national road infrastructures. High land prices also affect forestry potential. Furthermore, a specific forest project may cause disturbance to the biodiversity of the area, in both flora and fauna. Surrounding businesses may also be affected. Forestry requires regular maintenance for safety reasons. Not technology, but system innovation is the better word here. "Forest pilots" exists and their aim is better wood yield. R&D in more sustainable products for wood material are also present. New forestry concepts are mentioned as relevant for more afforestation, such as combining forestry with housing.

Green gas is scored 0.9. Biogas installations can be placed everywhere, but ideally near biomass hotspots, such as clusters of manure farmers, but also food factories, water treatment plants among others. It may be also useful when it is existing gas pipelines. Such installations usually cause more road traffic (trucks) and as a results, roads need to be strengthened. The installation may also require additional equipment's, such as storage facilities and additional space. In terms of technology dependencies, research in syngas may help with the roll-out of high quality gas, but is still in R&D. Biogas and green gas are market ready, but have low market adoption.

Waste is scored 1.0. The AVI's are positions near urban hotspots, and for a possible carbon capture system for the AVI, the value proposition becomes much better if they are also close to clusters of horticulture, for possibly reusing the captured CO_2. In terms of disturbance, the carbon installations may require quite large "internal" changes (extra factories; buffers, new chimneys,

water treatment), but few external changes. The technology uncertainty is considered proven, with TRL 6-7, but that is in the global context, the technology is never applied before in a large scale situation in the Netherlands. This may require changes in the supply chain.

In the Physical Interdependencies category, the following comments and remarks are recurring. For the question of embeddedness, it may be observed that most abatement options are dependent on clusters, the urban areas, the local environment, and hotspots. More specific clusters of horticulture (CCU and Waste), the neighborhood area (Housing), the local environment (Wind and Forest) and biomass hotspots. While it is generally not technically necessary, all options seems to be embedded in these sorts of socio-technical layers of society. The Wind case even have specific maps for these layers when it comes to wind park allocation at sea. For some these embeddedness affects the value of the case directly, such as the land price at the Forest case, and the transport distance for Green Gas and Waste case. On the other side, the abatement options also influences other operations, such as their own internal operations, for example requiring additional installations and facilities on site (CCU, Waste and Green Gas), and external operations, such as requiring others to relocate (Housing), businesses to adapt (Wind, Forest, Green Gas), ecosystem disturbance (Wind and Forest) and requiring new safety procedures (Forestry, and Waste). For the answer of technology uncertainty, all cases show that the technology is market ready. For specification, sometimes the Technology Readiness Level (TRL) is mentioned (CCU, Wind and Waste), others comment that the technology has low market adoption, and has to be cheaper and more competitive (Housing, Green Gas), while other mention that system innovation is needed (Forestry) first.

Behavior of the six cases

CCU is scored 1.1. For the consortium, and the related stakeholders, such as the port and the horticulture, it was fought for and most actors expected it. However, many are still outside this network. Opportunities do not come by often, and too few organizations have a demand for CO2. The CO_2 agenda recently is for some a pleasant surprise, for some not so. The CCU case is a slow sector, this is due to the design of the assets of the CO_2 emitting factories. The CO_2 market is a new market, and it could affect the way of working for the current supply chain partners.
Housing is scored 1.3. The Housing case doesn't seem surprise at all of the recent CO_2 agenda. Most have been working with sustainability goals for some time. The Housing case is not always happy with it though. This has to do with the housing stock, which is characterized by long lasting assets, but also by the housing installation and construction sector, they seem to struggle with the demand from project developers. The installation and construction sector is however entrepreneurial, but also quite opportunistic. Sometimes sustainability projects are not attractive due to relatively lower revenues compared to building new houses. For this sector the CO_2 targets requires a totally different way of working. The installation and construction sector need to change from delivering just a turn-key project to a performance based product with quality assurance. It is said to be a game-changer for the industry. For the end-users, the inhabitants and tenants, many personal and cognitive behavioral elements exist. For example, new installation systems at home require some time to adjust to. Habits need to change. The neighborhood also need to adjust, because sometimes the neighborhood may not like it, due to the unpleasant standardized looks of some installations. However, sometimes the refurbishment may also be wanted. As it increases the “status” of the house and thereby the house owner.
Wind at Sea is scored 0.4. The Wind case is not surprised by the new CO_2 agenda, and already quite accustomed to it. The wind turbine industry is grabbing much of the opportunities since 2017, 2015 and 2008. The wind turbine industry is quite organized, entrepreneurial and internationally oriented, and finds itself also a much organized environment compared to installing wind turbines on land, sometimes referred to as the NIMBY problem. Compared to the onshore wind turbines, the wind industry experiences more clear procedures. For the average households, the new system does not imply any behavioral changes, for nearby coastal

communities, special tools for stakeholders meetings are used to get coastal communities prepared, accustomed and deliberate their values to the new ocean view (3D visualization).
Forest is scored 1.1. The Forest case was a bit surprising for some governments. However, there is also a generally low awareness of the forestry sector. The sector here is also a slow moving one, and one that is also characterized by legacy properties. Opportunities such as these rare, forest owners are usually not business opportunistic. Forest have a general emotional attachment with people. This sometimes make it hard for people to understand practice of the forest management in the NL.
Green gas is scored 0.9. The diffusion of knowledge is good, the recent CO_2 agenda is not a surprise for the Green Gas case, but there is low awareness for biogas, as it needs to compete with other energy opportunities. The people are in the sector are quite entrepreneurial, but sometimes need a business trigger to grab opportunities (such as a manure overload). Bio-installations seem to take a lot from the entrepreneurs in terms of workload. It is often described as undertaken an entirely different business. This may not be the "passion" of the farmer.
Waste is scored 0.6. The Waste case is somewhat surprised by the recent CO_2 agenda, but is aware, and accustomed to policy changes. This is because, AVI's are historically "making a living from policy changes". The AVI's have generally a good diffusion of knowledge and acts frequently on core-business transcending opportunities. However, a real big change like this hasn't happened in like 20 years. The big change is characterized as changing the AVI's and its supply chain of working with delivering product that has to be "safe to consume" and of "food quality" for the first time.

In the behavioral category, the question of outside the scope is asked in the interview with a level of surprise for stakeholders. The answers given are mostly that the sector is a "slow moving one" and have "long lasting assets" (CCU, Waste, Forest). Sometimes they are not surprised, and comments such as accustomed to sustainability goals (Housing, Wind and Green Gas). However, "long lasting assets" is also mentioned in the Housing case, but they are still not surprised.

For the question of frequency of opportunities, many cases show a level of entrepreneurship. The level of entrepreneurship can be high (Waste, Green Gas, Housing, Wind), or low (Forest case). But sometimes the entrepreneurs can also be too opportunistic, such as in the Housing case, and sometimes they are entrepreneurial, only when triggered (Green Gas case). It could be that there are two notion of entrepreneurship: a policy one and a business one.

The behavioral change question is answered with varieties of "changing the way of working", "game-changer", "habits", "changing the business product", "emotional attachment" and "passion". The variety given is large. Sometimes, it is easy for the interviewees to imaging the changes, such as for the Housing and the Green Gas case, sometimes it is a general answer that the market is changing (CCU) in the sense that there is a complete new product in the market. The CCU, and Waste comment that CO_2 is now a natural resource, instead of a pollutant, and biogas can be made into green gas quality and therefore gas network alternatives and distributed as such, instead of just using it at a single location.

In this category, it was harder to group the comments together. The entrepreneurial comment, seems inconsistent, as lots of parties can be entrepreneurial, but under which circumstances is unknown. Sometimes, it's because of a business trigger (Green Gas), but sometimes it's from being aware and alert on such policy changes (Wind, Waste).

4.2 Comparison patterns of the six cases with theory

4.2.1 Patterns in the six cases

Patterns Cost and Finance

An important notion for this category is the business case. For some of the six case studies, the business case is a negative one, even including the most favorable subsidies, these are the CCU and the Forest case. In these cases the payback time is infinite in theory. However, new business cases in the future might change the current situation in these cases. For other case studies, the subsidy helps considerably, as can be seen in the Green Gas case. More than 100 tenders were awarded to promising business cases. However, this was just a one-time tender until further notice. The business case need to be proven, it seems. In other case studies, the tenders are not needed, but another type of arrangement is needed due to market conditions being too harsh still. For example, in the Housing case, a new type of contract within the industry (in Dutch: EPC, energie prestratie contract) makes easier to refurbish housing. In the Waste case, a certain type of arrangement in co-ownership with the municipality seems to open up conversations. Lastly, some business cases are common. This is so, for the Wind case, the first wind turbine park tender, without any subsidies, has been selected.

An interesting pattern can be seen when looked at the Cost and Finance category. Let's propose the following stages based on the empirical data of this category:

Table 16 – Proposed business case pattern for the C&F

1	The first stage is when business cases are being developed at the moment, or when there is a need for more variations of business cases.
2	In the second stage, business cases are still sought, but some projects are seen to be trying to apply for grants or have already applied for grants. Disclaimer: This has to be for the actual project, and not a grant for research or feasibility research.
3	In this third stage, business cases are still hard to develop, but the first few grants are awarded, some proposals are worth the business. However, grants may not be the main issue anymore. The business could be somewhat ready, but there are issues with the suppliers, contractors or the buyers. What is needed is economies of scales, less uncertainty in demand, more collaboration in supply. Grants may still be needed
4	Business cases have developed, public and private resources are known and sufficiently available, the industries are on it. Now, the first large project does not need any subsidy anymore. The issue rather becomes a supply-related issue, because the market is becoming saturated, such as the case in the Wind case.

Let's assume that the six cases belong to one of these four stages. Then the following could be assigned to the six cases. The first stage fits with the descriptions of two case: CCU and Forest cases. The second stage fits with the Green Gas case, as 118 tenders were awarded to a group of entrepreneurs in the milk industry. The third stage would fit the Housing case, as early market adopters exists, but for the majority, the market conditions are still rather problematic. The EPC arrangement with the industry helps in scaling up. The Waste case would also fit this stage, as arrangements with municipalities are made, and more AVI's are experimenting with carbon capture in practice. The last stage, fits the Wind case, as the first tender without any subsidy has been awarded. The first concerns about market saturations has been expressed as the business cases are quite becoming more mature.

Table 17 – Comparison C&F patterns with the Y-factor scores

Case	Business case four stages	Capex	Opex	Roi	Cost and Finance score and order

CCU	1	Hundred millions	€150	Infinite	1.9
Forest	1	3 billion	Low	Infinite	1.9
Green Gas	2	Hundred thousands	High	Ten years	1.6
Waste	2	Millions	High	Ten years	1.5
Housing	3	Thousands	Low	Less than ten years	1.3
Wind	4	14 billion	Medium	Ten years	1.1

If the order of the four stages were to put next to the factor scores, an inverse correlation exists, there is a pattern with the scores. Such patterns are also analyzed for other observations of the category, such as for the capex, the opex and roi in years (respectively capital expenditures, operational expenditures and return on investments). However, the logic of the pattern isn't as strong as the aforementioned "business case" pattern. The capex can be as low as several thousands (Housing), to hundreds of thousands (Green Gas), to millions (CCU, Waste) and billions (Wind and Forest), but the scores does show this pattern. The Wind case is scored with the lowest C&F elements, while being rated as the most expensive. This may have other reasons, for example for the Green Gas case, there are no straightforward goals, and it is unknown how many of such installation is needed. This is similar for the Housing case, it is rather unclear how much energy savings and therefore CO_2 savings is reached for what price exactly, the capex range in this case is the highest. The opex is high at CCU and the Waste, maximum are above €150 per ton. For Green Gas, the opex is high, and is dependent on biomass and gas prices. For Housing, the opex is low, and is dependent on energy prices. For Wind, the opex doesn't seem to be an issue at all. Also for Forest, the opex doesn't seem to be an issue at al. This also doesn't align with the scores. Last, but not least, the roi in years. There is the comment of a "design time" or an "operational time", such as for Wind, Green Gas and the Waste case. The equipment's just should or wouldn't last that long without replacements or relatively high maintenance costs, about 10 years. For the Housing, the design roi should be lower than 10 years. For the CCU and the Forest case, the is more than 20 years.

Based on these empirical patterns, the business cases for abatement options move from subsidized feasibility studies, to partly subsidized, to market or government arrangements, to fully privately funded.

Patterns Multi Actor

The Multi Actor category, scores the second highest among the four categories. For the Housing case, the high Multi Actor score stands out of all six cases. In the case description, one can see that this is because of the millions of house owners, which is unique among all cases. It could also be due to the multidisciplinary teams that is required. Even the specific numbers of such teams is mentioned, which is quite unique to all the cases. However, other cases also speak of such multidisciplinary or multi actor-teams, such as in the Green Gas, the Forest, Waste and the CCU case. However, the Waste specifically said that one such team would suffice, and the CCU only mentions one such team. For the Forest, there is the notion that not all crucial actors are involved in that one multi actor team. If CCU, Wind, Forest and the Green Gas case is assigned as have many "number of actors" and the Housing case would be millions, and the Waste case would be Few, the scores would show an inverse pattern as well, see table 18. For the multi actor teams, such a pattern cannot be seen as 300, to several, to one, and none, do not correlate with the scores.

Comments such as "public debates", "movements", "sentiment" were given, when asked about the types of actors. Some comments remain generic, but sometimes additional insights are given. For example, specific actors are mentioned, and the comment that they were lacking in the previously mentioned multi actor teams. For every case, similar labels can be given. For CCU it is controversial, due to a strong and negative historic project that is very

similar. For Housing, there are multiple conflicting sentiments, such as affordability and look and feel of the house. The Wind and the Waste case can be marked as supportive, as strong relationships have been built with related stakeholders. For the Forest case, there is public debate, recent activities have attracted governmental debate about the nature vs food, and nature vs natural resource. Lastly, Green Gas is described as having discussions for a long time about the role of bio-energy and what exactly sustainable biomass is. In comparison with the scores, there is no direct pattern.

When asked about roles and clarity, often comments about roadmaps or master plans are given. In some cases, such as the Forest case, the first drafts are made. Some are still looking for master plans such as in the CCU and Waste case. Other cases, such as the wind, have been issuing their 5th or more edition. The Green Gas seem to be having only one edition in the recent past, but a second one is said to be coming soon. For the Housing case, it seems that roadmaps are not mentioned, they may not be relevant. On the basis of the scores, this is the only case that did not mention it.

Table 18 – Comparison MA patterns with the Y-factor scores

Case	Number of Actors	Multi Actor teams	Types of actors	Roadmaps / Masterplan	Score
CCU	Many	Only one	Controversial	None	1.2
Housing	Millions	Multiple, but need around 300	Conflicting Sentiment	Not mentioned	1.7
Wind	Many	No	Supportive	Many	1.1
Forest	Many	Yes	Public debate	First	1.1
Green Gas	Many	Yes	Discussions	First	1.2
Waste	Few	Exactly one	Supportive	None	0.9

For the roadmaps / masterplan, disclaimers are sometimes given, such as first since 20 years such as with the Forest case, the Green Gas case, seem to have one just couple of years ago. Comparing the comments with the scores, the Housing case stands out. The items and their nominal scales also stand out. Looking at the number of actors, the higher the scores, the higher the number of actors. However, other subfactors do not create a pattern with the score. Observations that were not grouped together are comments about the thousands or millions actors or specific actors name, such as cattle farmers, households, biomass traders. Comments that were left out too are comments about winning tenders, comments about the market, national or international, guidelines and procedures, governments being involved or not, and the details of the public debates.

Based on these empirical patterns, the existence of few or zero multi actor teams, does not matter much for the multi actor complexity. The existence of necessity for multiple actor teams does.

Patterns Physical Interdependencies

The Physical Interdependencies category ranks third in the overall score. The category seems to be quite medium, all case scores are 1 rounded off. As for the subfactors, the embeddedness stands out just a bit, but it isn't much.

The embedded factor is often accompanied with comments such as clusters, urban areas, the local environment and hotspots. The clusters could be clusters of horticulture and industries, such as in the CCU case and the Green Gas case. The Wind case have specific layers of map to show the embeddedness of the offshore wind parks in relation to its environment, but also the social environment, such as navigation routes, and oil platforms. For the Housing case, the embeddedness is quite complicated. It depends on the age and other characteristics of the building, the street, but also the neighborhood and city planning. Sometimes this question is not well enough understood, and is answered by "technically it is not dependent of anything". However, sometimes even urban area density determines the

embeddedness in some case studies, such as the Waste case.

In relation to disturbance, the answers vary between disturbance to disturbing own daily operations, to disturbance to the external environment. For the Waste case, the current waste incineration process may be affected, as well as the CCU case. The external disturbance would be the local residents in the Housing case, they sometimes need to relocate. For home-owner, the perspective is reversed, and it is mostly an internal disturbance for them. However, external disturbance remains, such as changing the street image. For Forestry, every project depends on the external localities. However, for Forest, the external biodiversity might be affected. A notion should be made, sometimes the embeddedness and the disturbance questions seem to be interrelated with each other in the comments. For example, the biodiversity could be disturbed in the Wind and Forest case, but it could also be that the biodiversity requirement serve as a hard requirement for the project, and thereby embedding the projects in an environmental structure.

For the technology uncertainty, the Technology Readiness Level is often mentioned. The specific level is given for the CCU, the Waste case and the Wind case. Others offer comments that resembles the qualitative scores, for example in the Green Gas. However, in the Green Gas case the range is high, some technology are “market ready”, and some are definitely still in R&D. For Housing, the technology is proven, but has very low market adoption. The TRL range from 1 to 9.

Table 19 – Comparison PHI patterns with the Y-factor scores

Case	Embeddedness	Disturbance	Technology Readiness Level	Score
CCU	Industrial clusters	Internal	3 to 6	1.4
Housing	Street & City planning	Internal & External	1% market adoption	1.4
Wind at Sea	Marine space	External	Very high	1.2
Forest	Regional planning	Internal & External	Not relevant	0.8
Green Gas	Hotspots	Internal & External	Large range. From R&D to some market adoption	0.9
Waste	Urban areas	Internal	6 to 7	1.0

In comparing the Physical Interdependency category, the observations, and their patterns in table 19, do not show any direct relationship with the scores of the Y-factor. Only the TRL has an ordinal scale, but comparing it with the scores, there is no correlation with the TRL pattern. For the embeddedness question, comments that were omitted are comments about the locations of suppliers and producers, about space being limited by a regional plan or are too crowded. For the technology question, comments about more demonstration projects and that R&D is needed are also omitted, as it seems that every case needs them in some form.

Patterns Behavioral

The Behavior category scores the lowest of the four categories. The Wind case scored the lowest with a score of 0.4 and the highest score belongs to the Housing case, with a score of 1.3. The range between these two is the highest among the cases. However, with a range of 0.9, it does not fall far from Cost & Finance (0.8) and Multi Actor (0.8).

In the six cases, some cases are surprised, for example in the forest case (the provinces were surprised), the waste case (the AVI's themselves), the green gas case (the farmers). However, there were other in the same cases who were not surprised, such as in the Green gas case, where the overarching platform organization has contributed to the past CO_2 agenda. The arguments are inconsistent, for example, sometimes because the sector is a slow mover, due to long lasting assets and are therefore surprised (CCU, Waste, Forest). However, the Housing, and the Wind case, also have long lasting assets, but they are not

surprised. For the question of frequency of opportunities, some cases seem to be more experienced with policy changes, and some are better with market changes. For example, the waste sector exists through policy changes, while the horticulture in the green gas cases are much more entrepreneurial and willing to take risks compared to the waste case. In the forestry, both policy or market change mindset is not common at all. The housing sector seems to have the most behavioral change elements. Inhabitant's habits need to change, and the installation sector need to change from providing just a turnkey product to a project that performs well over time, it was said to be a "game-changer". For the Forestry there is an "emotional attachment", the Waste case is talking about "changing a different type of product", and the CCU is talking about a "whole new market". For the Green Gas case, the descriptions of behavioral change is like undertaking "a new business". For the Wind case however, there is few behavioral changes reported. Only some view pollution may have been mentioned.

Table 20 – Comparison Beh pattern with the Y-factor scores

Case	Out of scope / surprise	Frequencies opportunities	Behavioral changes	Score
CCU	Somewhat surprise	Market changes	Whole new market	1.1
Housing	Not surprised	Opportunistic	Habit and game changer	1.3
Wind at Sea	Not surprised	Policy changes	New coastal view	0.4
Forest	Somewhat surprise	No business mindset	Emotional attachment	1.1
Green Gas	Somewhat surprise	Market changes	A new business	0.9
Waste	Somewhat surprise	Policy changes	New product requirements	0.6

The following scales for the subfactors can be found. In behavioral changes, on the basis of the scores, it could be that habits and game changer entail more behavior changes than a whole new market, which is about the same as have an emotional attachment to the key issues of the abatement option. New business entails less behavioral changes, and a new product even less. However, only having a different view, accounts for the least behavioral changes.

4.2.2 Comparing theories with patterns

The observations of each category are compared, and useful patterns are found in the interviews qualitative data (the narratives). Patterns such as the four stages of business cases, multi actor teams with roadmaps, and more are proposed in the previous section. The subfactors have aided in producing comparable items. However, ordinal patterns in the scale, were not supported by the scores.

Cost & Finance

In section 2.5 and 2.6, the theoretical framework for Cost and Finance was discussed. From a transition theory, the specific of the costs and finance are less relevant, especially if they are from a single project. Costs affecting multiple organizations, is more interesting, as a level playing field should exist between the organizations in the sector.

Comparison theory and patterns

On the basis of the observations of patterns in section 4.2, the most noteworthy notion for the category is the business case and its four stages. Better business cases can be induced by subsidies, but also by market mechanisms and arrangements. Four stages have been presented of how business cases may develop, and aligned these with the order based on the Y-factor score, see Table 21.

Table 21 – Comparison the C&F pattern of business case with theory

Case	Four stages	Cost and Finance score and order	Multi-phases from transition theory
CCU	1	1.9	Pre-development phase
Forest	1	1.9	Pre-development phase
Green Gas	2	1.6	Take-off phase
Waste	2	1.5	Take-off phase
Housing	3	1.3	Acceleration phase
Wind	4	1.1	Stabilization phase

As can be seen from table 21, the scores and the stages are inverses of each other. The higher the Y-factor subscore, the lower it ranks on the four stages. From a transition perspective, this resembles the four phases of 1. "Pre-development", 2. Take-off phase, 3. Acceleration and 4. Stabilization phase (Loorbach & Rotmans, 2006). In our six case, the description of the first phase of the transition theory is about the development of viable business cases and the activities are knowledge and research based. The second stage is the take-off phase, where the first businesses and their partners enter the market with subsidies as a crucial part of the business case. The third phase, the market matures and create more favorable conditions. Parties may look for market arrangements for risk sharing, instead of subsidies only. In the final phase, business cases exists where the government does not provide subsidies at all, and where parties worry about a surplus in the market that may be too large and ponder about the negative effects.

From the transition theory, it is somewhat expected that the investment costs are high, and with mostly long payback time. However, it was also noted that these concepts are not that relevant. In the empirical data this can be found too. The notion of difficulties with financing also does not reflect in the transition theory. In the observations, one may see landscape development (MLP), such as "favorable market conditions" or the availability of "subsidies and grants". The first depends on the economy, and the latter depends on the political dynamics.

Multi Actor

In chapter two, the subfactors of the Multi Actor Complexity can be best explained by the Multi-Level Perspective (MLP). The MLP discusses the wider and larger landscape development, such as wider public tendency. At the regime level, groups of engineers, firms, scientists, users, policy makers and societal groups are active (Geels and Kemp, 2007). A Transition Arena (TA) exists too at this level. In the TA, a core group of innovators and visionaries can be identified. At the niche level, new technologies are developed, experiments are done. In time, they may later become the norm and breakthrough the regime. In the MLP, innovations are explained by niches breaking through to the regime level, provided that the niches can survive the market conditions.

Comparison theory and patterns

Based on the observations of the patterns in section 4.2, visualizing using the three levels from the MLP framework has been found useful. Three actor constellations has been visualized and all six cases can be characterized using these actor constellations.

The first type of actor constellation is visualized as having many fragmented actors at the niche level, see figure 18. At the larger regime level, the actors are quite established and have formed similar fragmented, strong relationships. The market is somewhat established, and needs developing. However, this is also is fragmented, and regional differences in markets may be large. At the landscape level, the developments are weak and is characterized by sentiments of low CO_2 priorities.

The Housing, Forest and the Green Gas case, fit the description of this actor constellation. In the comments of the Housing case, one may find many housing corporations

and homeowners, and their interactions with project developers are slow and distant. In the Forest case, large group of yet to be organized land and forest owners for the forest projects are found. In the comments, the wider forest “Actionplan” exists, but owners of forestry land, such as the provinces and new forestry ideas for new areas, are yet to be fully involved and organized. In the Green Gas case, the many farmers are aware, but the comments show that there is also a high dependency with the many biomass actors. The two are not that organized in the field of bio-energy. Signals for this statement may come from a recent tender, which was only possible through a multinational actor in a very specific regional area and agriculture industry (milk). Another signal for the weak organization and fragmented structure is the comment of competition between the wider group of renewable energy and bio-energy.

At the regime level, the Housing case fits this actor constellation, because it shows that each tenant and home owner have dependent relationships with strong, protective and long standing actors such as municipalities and housing corporations. This is similar for the farmers and horticulture with their strong branch associations. In the comments, one may find that the horticulture branch association is known for its strong lobby nationally and locally. The forest case show a similar situation, the forest regional associations and their environmental institutions are well organized, and compliance with biodiversity is sometimes mentioned as one of the core values. In the case descriptions, the regimes in the three cases seems to be quite established, and it may be said that the cases have a long history of working with different types of sustainability themes. For each of the three cases, efforts to transcend niche players to the regime level can be seen too. In the Housing case, a platform organization (Energiesprong and the successor Stroomversnelling) aims to unite the construction, and installations actors with homeowners, through financial arrangements with governments and other institutions. Interviewees from the Green Gas case, comment that a joint government and industry program (Kas als Energiebron) helps in knowledge exchange, subsidy regulation, and creating affordable technologies. In the Forestry case, an industry plan to the government (the "Actieplan Bos en Hout") opted for new afforestation plans in several regions. While these initiatives may become more entrenched at the regime level in the future, the efforts seems to be localized. The comments in all three cases indicate rather that this is because of the localized character of the case instead, and a uniform and centralized effort may never happen, as it may not fit the three cases. Comments such as the 300+ multidisciplinary teams (in the Housing case) underpin this. However, some efforts such as the “Kas als Energiebron” in the Green Gas case, seems to be part of the regime, as it is governed by large institutions in the horticulture, and that some type of a centralized may be possible.

In these cases, the landscape developments are rather weak or are characterized by lower sentiments of CO_2 priorities. For example, in the Housing case, the sentiment of whether green initiatives should precede affordability and comfortable living goals is dominant. In the Forest case, the nature quality and legacy values also show a higher priority than CO_2 goals. Similar for the Green Gas case, the CO_2 goals exists, but there are many other renewable energy initiatives as well, such as geothermal, and solar energy.

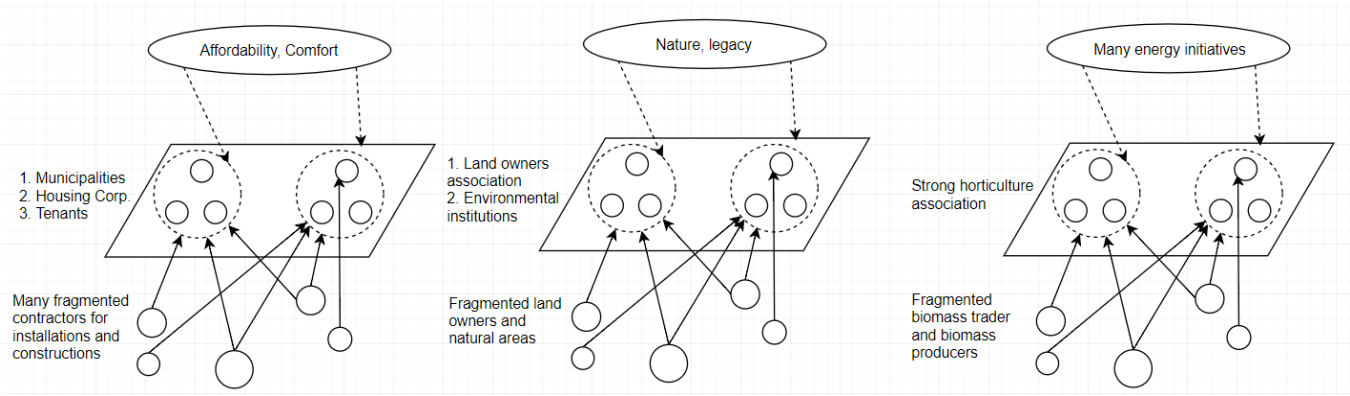

Figure 18 – From left to right, the Housing, Forest and the Green Gas case

The second type of actor constellation can be explained as having few niche partners, but a strong, and small professional network at the regime level, see figure 19. This type of actor constellation is characterized as having counterproductive landscape development. This type of actor constellations can be seen in the CCU and the Waste case. In the CCU, the comments of the interviews show that a small consortium of around 20 partners has been formed. Moreover, the comments show that dependencies exists at different levels, and that the market for CO_2 is underdeveloped, it may be said that the regime is connected but strong and closed. In the Waste case, the niche players are small in numbers, but the branch association is a strong club. The branch association of the 13 AVI's is quite active, the 13 plants know each other, and work with each other in various working relationships. However, not all actors are aligned with the CO_2 goals, and a representative team with a CO_2 mission is missing. The landscape development is marked as not supportive, however, this is mostly true for the CCU case. While the interviewees experience a much controversy regarding carbon capture and storage (CCS) and utilization (CCU), the Waste case doesn't seem to be affected as much. AVI's in the Waste case too are building carbon capture installation, but they seem to be far less sensitive to the controversy. In the Waste case, long lasting relationships with the surrounding municipalities and citizens groups can be observed, it may be due this legacy that the Waste case is less sensitive to the negative carbon capture discussion.

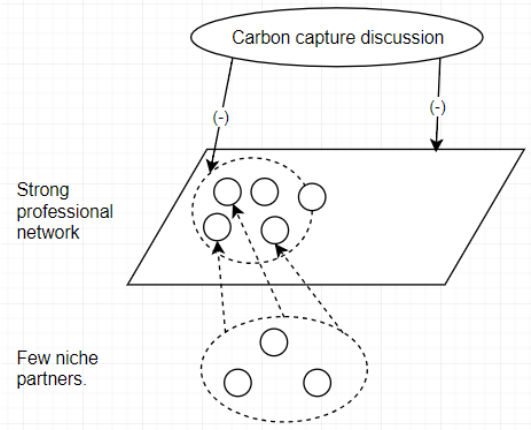

Figure 19 – The CCU and the Waste case from a Multi-Level Perspective

Lastly, the niche level could be represented by large groups and strong interconnectedness. The supply chain partners are quite aware of each other, and are aligned. In the regime level, the rules of the market are clear, and the landscape development is cooperative. Such conditions can be seen at the Wind case in figure 20. At the niche level, the niche parties be aligned and organized. In the interviews, one may find comments revealing that the steel pylon makers are working together with the turbine engineers and the blade welders. While these companies serve the international market, they seem to perform well in the Netherlands as well. Reasons for this level of collaboration and aligned could be that the case is a very specialized and technology driven domain. Interviewees comment on experiencing structured procedures and good stakeholder's interactions. The general notion for wind is also good, there is a history of recurring roadmaps, and some interviewees comment metaphorically that the case has strong "wind in its back".

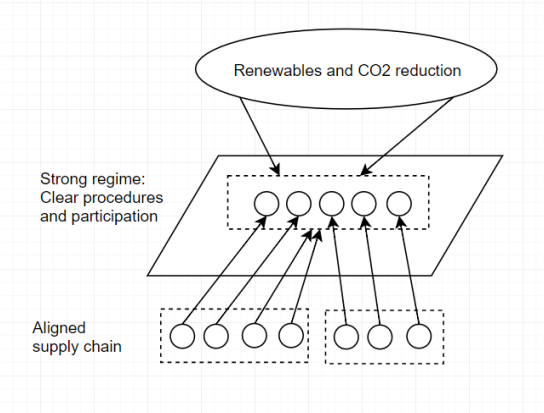

Figure 20 – The Wind case from a Multi-Level Perspective

By comparing the observations with the Multi-Level Perspective, three archetypes or configurations of the actor constellation is shown on the basis of the six cases. For the construction of these actor constellation, the number of actor question is the least useful. The three actor constellations do not align with the scores of the Multi Actor category. The CCU and Waste score 1.2 and 0.9 respectively, while the Wind case scores 1.1, and the three cases of the first actor constellation, score 1.7, 1.1 and 1.2 for respectively Housing, Forest and Green Gas.

Table 22 – Comparison MA pattern with theory

	Niche level	**Regime level**	**Landscape level**
Housing	Fragmented niche players	Strong, but localized	Weak and low priority
Forestry	Fragmented niche players	Strong, but localized	Weak and low priority
Green Gas	Fragmented niche players	Strong, but localized	Weak and low priority
CCU	Few niche players	Strong and small network	Unsupportive
Waste	Few niche players	Strong and small network	Unsupportive
Wind	Aligned and adjusted niche players	Strong regime, but aligned	Supportive

Physical Interdependencies

The Physical Interdependencies category focus more on the technical perspective. In chapter two, it has been discussed that systems are composed of subsystems and interact with other subsystems through interfaces. As a result of these systems interactions, transitions may occur as changes from a large socio-technical system to another (Geels and Schot, 2007). These interfaces can be quite physical, for example the geological layers of the ground for an underground infrastructure. In this example, the technology might be embedded in the geological system, as some layers might be unsuitable for underground pipelines. Transitions therefore have an embedded character, it starts from a certain point where it is the most favorable or where it may adapt the best. Additionally, systems will interacts with other systems and subsystems. Other systems will be disturbed, for example the urban system, the environmental system, and the transportation system among others. If these disturbance are not accounted for, the “regime may strike back” (Loorbach & Rotmans, 2010, p. 244). Transitions may also be dependent on something more conceptual, but equally significant, that is the general technology advancement. This larger technology system is slow, and is characterized by its global connections and its widespread influence. Think of the electric car

engines or the technology for batteries. These technology systems have their own life cycle. Newer technologies to drive the transition might be still in research and development or may not have survived the trial of the harsh market conditions. Transitions may be dependent on such gradual systemic change.

Comparison theory and patterns

On the basis of the observations and the patterns, see *few* notions in section 4.2 corresponds with theory. First, in the observation, the Technology Readiness Level is often used. In transition literature, this is not mentioned. Second, in the observations, the question of embeddedness is often replied with a spatial component, but also from a planning approach. In literature, this is emphasized as more technical, such as from infrastructures, or power grid. Thirdly, the disturbance factor is quite similar to that of literature. Moreover, none of the patterns observed correspond to the scores.

In the Wind case, the embeddedness is for example clearly delineated in a map offshore. For the Green Gas case, the area with an increased biomass supply, a biomass hotspot is far more suitable for a gas installation. For the CCU case, the carbon capture installation is only viable where there are high intensity of clusters of CO_2 supply and demand. This may be as simple as a two point graph system. In literature, the spatial dimension or the embeddedness in existing urban or regional planning is not as apparent. The focus in literature is more technical, such as road infrastructure, electricity grid, pipelines or certain geographical layers. In practice, instead it is embedded in the street, urban, regional, industrial and marine space planning. The disturbance subfactor is quite reflected in the literature. Projects will be a disturbance to the human and the natural environment and from a transition perspective this has to be accounted for eventually. In the observations, procedures and permits are often seen to be referred as part of this process. In the observation, a difference can be made for internal and external disturbance. This depends on the perspective of the transition object. For example, in carbon capture installations, the CCU and Waste case, the CO_2 sources, the chimneys, they mostly disturb their own internal processes, but also their own core business. Moreover, in the observation, there is sometimes confusion regarding the relation between embeddedness and disturbance. For example, sometimes the disturbance can be so great that it acts as requirement from an embedded system. For example, the disturbance to natural environment, as some areas simply prevents a transition project to happen, either through a hard environmental law, such as in the North Sea.

The commonly used Technology Readiness Level (TRL) for assessing the technology uncertainty is not seen in the assessed transition literature. In transition literature, demonstration projects (the housing case), and research in feasibility (CCU) and research in R&D is important, but the theory does not specifically look into levels of technology. Niches develop and the technology options should be kept open. There is a notion that some niches win, while other niches loses, it suggests a dichotomy. In practice, there are different types of technology levels that are relevant. Different types of experimentations are needed. The observation suggests that for different percentage of market adoption, different experimentations are needed. This can be supported by the Green Gas case and the Housing case. However, from the six cases it is unclear to what TRL that may correspond.

Behavioral

From a transition perspective in chapter two, thinking outside the box is a necessary mechanisms within the niche level. Pressures may help the niche level to behave innovative. In transitions, sometimes it only depends on a few individuals. These may be employees, customers, engineers and policy makers. When there are many opportunities, the abatement options may picked up by the few, but crucial frontrunners among the employees and stakeholders. Creating such windows for opportunities may help the case reflect and take advantage of trial and error, and second or third order learning effects. Sometimes when the regime shifts or changes, a whole set of existing shared routines in a community of engineers may change along too. These changes are also reflected to changes on an individual level,

and may change the way how people work, live and leisure. The end-users of the abatement options may react or foresee this, and may experience, depending on their view, positive or negative behavioral changes.

Comparison theory and patterns

On the basis of the patterns in the observations, *few* notions corresponds with transition literature. First, the element of surprise or being out of the scope of the transition is only seen as somewhat surprised in four cases, and not surprised at all in two cases. Second, the frequency of opportunities

Surprises creates windows of opportunities for niches to breakthrough and regimes to change, according to transition theory. The element of surprise was expected in the cases, however this was not shown in the results. The answers sometimes refer back to roadmaps and other questions whether people are aware and informed. However, this is not something this is not expected. It was expected to see a general surprise wave across the sector. This may be hard to assess in such a research setting.

In regards to the question of frequent opportunities, the expectation was high frequency, but the observations show a medium score. For the Forest case, there was never a large business ambition. The ambition is to preserve nature and upkeep a healthy living environment. Land-owners are asked to run their land as another type of company, which doesn't happen frequently. The same has been said for the Green gas case, the bio-installations are an even bigger undertaking, creating an impasse for farmers. The Wind case has moved away from onshore land for the reason to avoiding large infrastructures behind someone's backyard. In public stakeholder meeting, 3D visualization tools has been used to show, not tell, how the view in many beaches would look like. Such tools seemed to have positive effects on people behavior. However, this type of behavioral element seems quite unique, and similar behavioral mechanics has not been found in other cases.

From a transition perspective, large behavioral changes should be seen in all six cases. Indeed this is the case. In the housing case, the installation and construction sector are changing, so are the inhabitants while they learn to live with new energy systems. For these actors, many behavioral elements exist in the housing case. In the CCU case, a whole new market is being created and the business community, the buyers and the sellers, are still figuring trying to out the rules of this new CO_2 market. In the Waste case, the story is somewhat similar, the supply chain partners have to deal with selling a whole new kind of product, namely CO_2. This is perceived as quite different, because in the past, AVI's have only sold non-food quality products. In the Green gas case the gas grid is changing slowly but surely into a more decentralized gas grid. Multiple injection points for the gas network are being installed. Farmers may be running a small energy company (gas producers) soon, however it might not fit the passion of a farmer. Another behavioral change in the Green Gas case are the traders or suppliers of biomass. For now, the biomass market seems not transparent, and additionally the biomass producers may not be able to handle an exponential growth of the demand for biomass. The results show many variations of the answers. This may suggest that the factor that specification is needed.

4.2.3 Comparison expectations with observations

The expectations from the theory and the observations have been summarized in the table below. The numerical scores are rounded off to the nearest score of low, medium or high. The majority of the direction of the subfactors aligns with the observations. For each of the 13 subfactors, three expectations could be given; they generally align with notions of low, medium and high. Out of the 13 subfactors, 5 expectations did not match with observations, see table 13. The high embeddedness was the most unexpected. As mentioned this may be a respondents also including sociotechnical systems, instead of the technical system. This is followed by few elements of surprise. A high surprise is expected. More importantly, the insights from the MA category fits very well into the expectations derived from transition theory. The observations fit the theoretical notions of Transition Arena. However, many types of actors

are expected, but in the observations only medium amount of actor types are experienced. Furthermore, the medium disturbance level was also not expected, as well as medium opportunities, in respectively the PHI and the Beh category.

The findings derived from this comparison could help in understanding the relation between the Y-factor and transition management theory. For the C&F category, TM has provided little in terms of expectations. Notions from neoclassical economy seems to be align with the observations. The MA category only slightly differs from the observation. The

Table 23 – Comparison expectations from theory with observation

	Subfactors of the Y-factor	Expectations	Observations
Cost and Finance (C&F)	• Investment costs • Payback period • Difficulty financing	• High • High • High	• High ✓ • High ✓ • High ✓
Multi Actor (MA)	• Number of actors • Number of dependent actors • Number of types of actors • Clarity roles	• High • High • High • Medium	• Medium ✗ • High ✓ • Medium ✗ • Medium ✓
Physical Interdepen-dence (PHI)	• Physical embedded • Disturbance regular operations • Technology uncertainty	• Low • High • Medium	• High ✗ • Medium ✗ • Medium ✓
Behavior (Beh)	• Out of the scope • Frequency opportunities • Behavioral changes	• High • High • High	• Low ✗ • Medium ✗ • Medium ✓

4.3 Perspective analysis of the six cases

In the case studies multiple perspectives are used for one single case. Three perspectives are incorporated to offer nuances to the case wherever it is deemed necessary. The three different perspectives of the six cases are analyzed in this section. The three perspectives are the Stakeholder perspective, the Knowledge perspective, and the Government perspective. Out of the 21 interviews, 6 are from a Stakeholders perspective, 8 from a Knowledge perspective, and 7 from a Government perspective. For clarity, the Stakeholder perspective is characterized by having an actual stake or asset in each case, or representing companies having such stake. The Knowledge perspective may be from academia, or technology consultants. The Government perspective must be from a policy officer from a ministry, agency or municipality. The radar chart and for the individual scores, a histogram is also presented.

On the basis of the three differentiated perspectives, the Knowledge and the Government perspective seem to be the most similar to each other, see figure 21. The Stakeholder is seen to be different from the other perspectives. This is mainly due to the Physical Interdependencies category, the difference of 1.4 with the score of 0.9 and 1.0 of respectively the Knowledge and the Government perspective is apparent. This is a difference of at least 0.4 and this may suggest that extra attention should be given when taking into account the Stakeholder perspective. The Stakeholders may be generally more strong in assessing the Physical Interdependencies, than the other two perspectives. This could make sense, as the Stakeholder may be physically the closest with abatement options, and may deal with them on a more daily basis. Additionally, the Stakeholder also has different scores for both the Finance & Cost and Multi Actor category, while the Knowledge and the Government perspective share the exact same score for the two category. The difference is 0.2. It should be noted that this is twice as low compared to the difference in the Physical Interdependencies category. The higher score on Finance and Cost could make sense, as Stakeholders has a stake in the abatement option, and may deal with the finance quite directly. The lower score in Multi Actor could also make sense, as Stakeholders deal with a more focused and

specialized working environment, and hence experiencing less multi actor dynamics in comparison with Governments and Knowledge organizations. The behavioral category performs similarly throughout the three perspectives.

The similarities and differences in the three perspectives do not behave out of proportion and can be reasonably explained. However, this may still mean that the scores of the Y-factor may need to take into account the different perspectives. A limitation of this research is that the cases may provide too little data for actual correction of the data. A between-group statistical analysis with more cases (>30) per perspective may be further researched. The thesis therefore did not adjust the scores of the Y-factor in any analyses. However, the notion should be given that for every case the Physical Interdependencies may be overestimated. A similar overestimate notion should be given for Finance and Cost, and for Multi Actor, the scores may be underestimated. The magnitude of the effect of the latter two categories may be twice as low as that of Physical Interdependencies.

While this perspective analysis resulted in no implications for any analyses, it can be said that the comparison between three types of interviewees made sense, and that the Y-factor can be used this purpose.

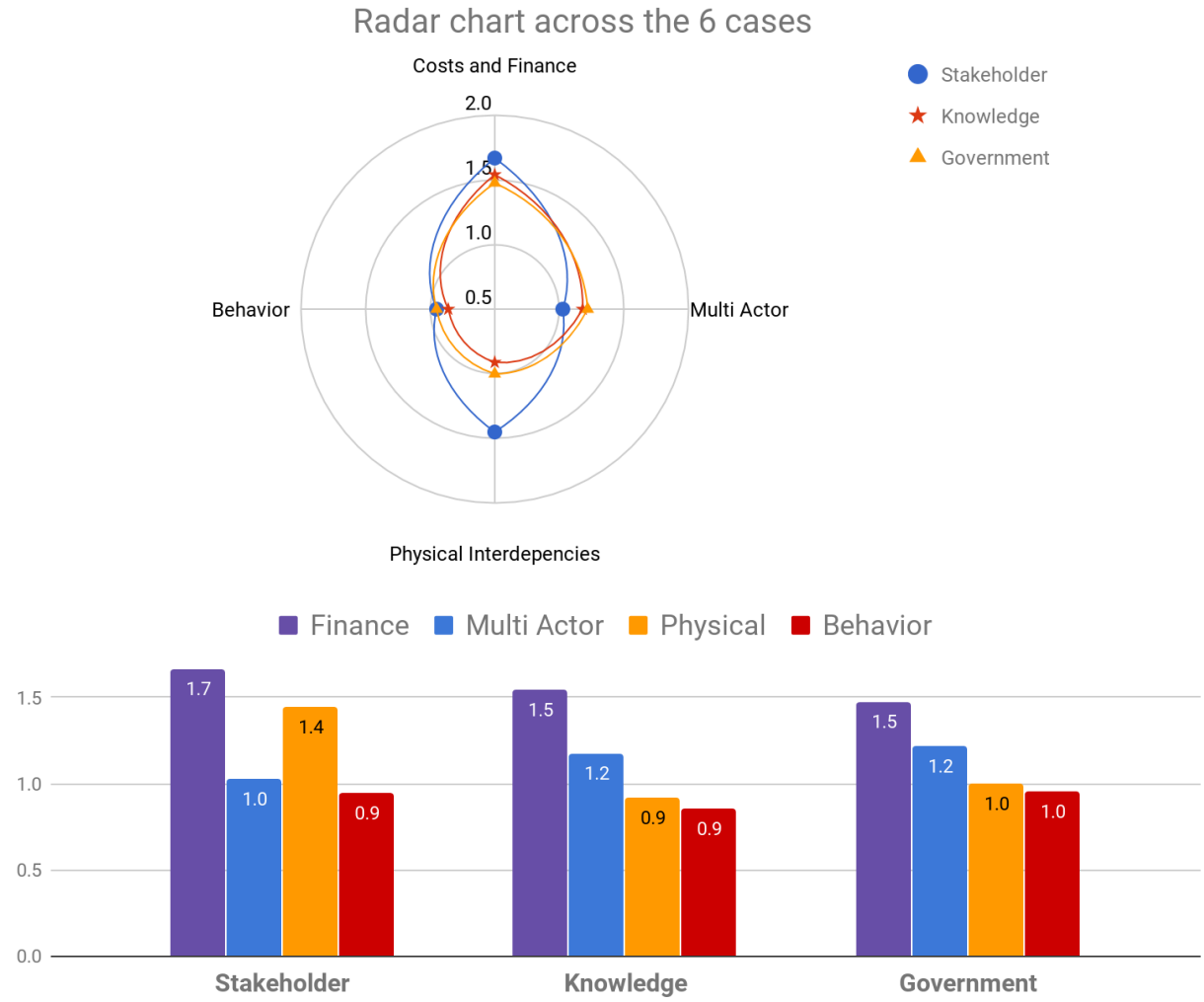

Figure 21 – Perspective analysis on all six cases

4.4 Comparison with the MACC

In discussing the challenge of the MACC and its lack of non-economic insights, the abatement options assessed with the Y-factor is presented side by side by the MACC. To compare, the

curve of the MACC and the curve of the Y-factor will be used. The Y-factor is composed with the Cost & Finance category for the very purpose of this comparison. It can be said that the Cost and Finance category in the Y-factor is for simulating the MACC. Constructing the MACC in its original way for the same abatement options in Netherlands requires an additional study. This is left out in this thesis. Two comparison are done nevertheless;

1. The comparison of the Cost & Finance category (simulated MACC) with the combined score of Multi Actor, Physical Interdependencies and Behavior.
2. The comparison of the combined score of Multi Actor, Physical Interdependencies and Behavior, with the scores of a study of the MACC in 2009 (See Appendix F).

4.4.1 Comparison of the two Y-factor curves

Figure 22 – Comparison two curves from the Y-factor

The two curves from Figure 22, is constructed in a straightforward way: the averages of all scores per category and per case are computed, and aligned in a graph using Excel. Scores are not rounded off, until displayed in the graph.

The Housing case differ the most in order, by a difference of 4. The order of the two curves are presented in Table 24. The order change in itself is not interesting, but on the basis of the Y-factor (with three categories) the Housing case is more likely to be explained by Y-factor as it scored the highest in the Y-factor. However, caution is advised here, as the one with the high scores in the Y-factor doesn't mean that the abatement option is full of difficulties or complexities. A high score simply means that the underlying factors of the Y-factor (MA, PHI and Beh) are scored high. As noted for the MACC, a low cost does not imply that the abatement option will be easy to implement, neither does high cost imply that abatement options do not get implemented. This is similar to the Y-factor, a low score does not mean that it is easy to implement, as much as a high score does not mean that it is difficult to implement.

On the basis of these two curves and assuming only these six cases, the abatement options scoring high in the Y-factor curve, but low on the MACC, may be more likely to be explained and affected by MA, PHI and Beh factors, than by Cost and Finance factors. Assuming that the three lowest are low, and the three highest are high, the Housing case fits this explanatory conclusion. Similarly, cases where the Y-factor is low, but the Cost and Finance score is high, the abatement option will be more likely to be explained by Cost and Finance factors, such as Forest. No such explanation can be given for cases where the Y-factor and the Cost and Finance are both low or high. The Green Gas and CCU is both high in both curves.

Table 24 – Comparing the Y-factor with the C&F score (simulates MACC)

Y-factor with three categories: Multi Actor, Physical and Behavior	**Curve with only Cost and Finance (Simulates the MACC)**	
1. Waste	2. Wind at Sea	Δ1
2. Wind at Sea	6. Housing	Δ4
3. Forest	1. Waste	Δ2
4. Green gas	4. Green gas	Δ0
5. CCU	3. Forest	Δ2
6. Housing	5. CCU	Δ1

4.4.2 Comparison of the curves from the Y-factor and the MACC

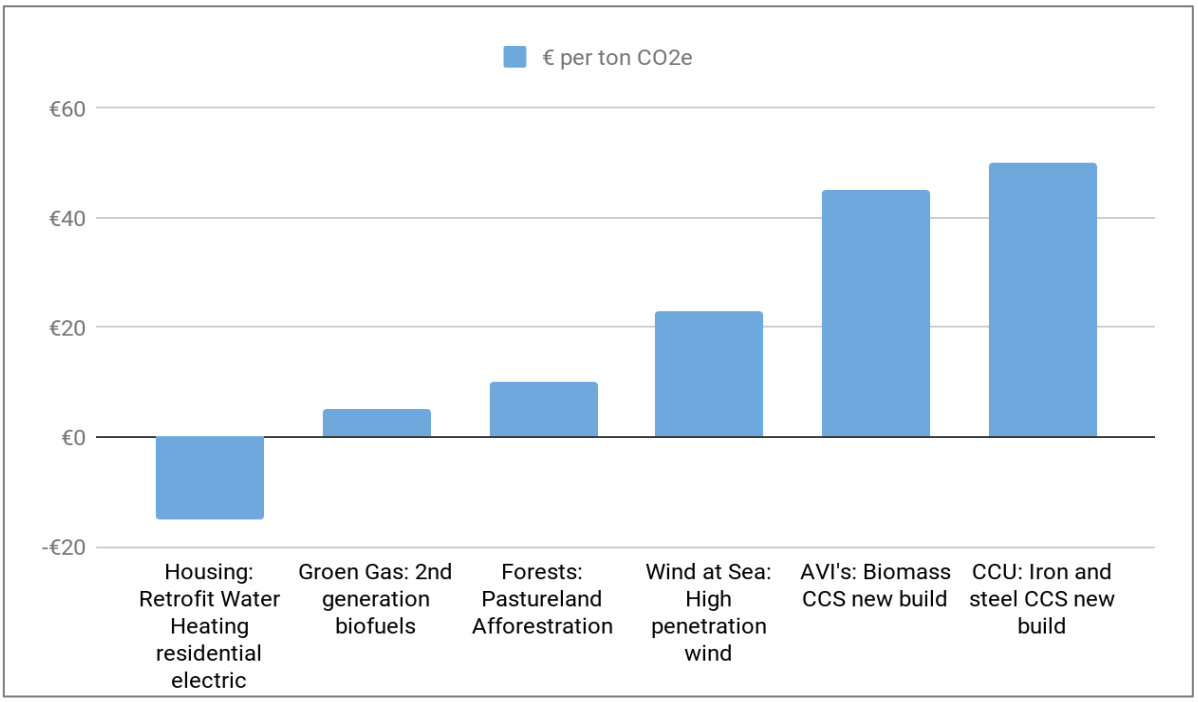

Figure 23 – Simplified MACC based on data from Naucler & Enkvist (2009)

The MACC in figure 23 is computed by solely reviewing the similar abatement options curves in the McKinsey report by Naucler & Enkvist (2009). See appendix F for used values. While having similar descriptions in the graphs, it is unknown whether any of these cases from the report shows any large similarities with the cases that have been assessed for this thesis. Moreover, the data from the report may be overdue for some time now. Regardless, low scoring abatement cost are placed to the left. In figure 23, the width of abatement options do not represent the CO_2 abatement potential, as is the case in the original MACC. For the purpose of comparing with the Y-factor only, the x-axis is left out.

On the basis of the MACC and the Y-factor curves, the difference is even larger then in section 4.5.1. Two cases stand out now with their high scores, the Housing and the Waste case. The Forest case does not stand out anymore, as it is scored in the rankings. Similar conclusions can be given, as in section 4.5.1, the Housing case may be better explained by the Y-factor than by the MACC, as the Housing case score high in the Y-factor, but low in the MACC. The Waste case may be better explained by the MACC than by the Y-factor, as the Waste case is scored high in the MACC, but low in the Y-factor. Two more cases stand out, if the same assumption is made about low (three lowest cases) and high scores (three highest cases), that is the Wind and the Green Gas case. The low score for the Y-factor and the high score

for the MACC, may indicate that the Wind case is better explained by the MACC than the Y-factor. Inversely, the high score for the Y-factor and the low score of the Green Gas case may be better explained by the Y-factor. The CCU case is high in both curves.

Table 25 – Comparison curve from the Y-factor and the MACC

Y-factor with three categories: Multi Actor, Physical and Behavior	**The simplified MACC reconstructed from the 2009 MACC report**	
1. Waste	1. Housing	Δ5
2. Wind at Sea	2. Green gas	Δ2
3. Forest	3. Forest	Δ0
4. Green gas	4. Wind at Sea	Δ2
5. CCU	5. Waste	Δ4
6. Housing	6. CCU	Δ1

In discussing the Y-factor in relation with the MACC, the empirical data may suggest that in some cases, the Y-factor could perform better in explaining the abatement options implementation factors. In the two comparison, the Housing case has been found twice to perform better than the MACC. However, it should be noted that the data also show that in some case the MACC would outperform the Y-factor. Further research is needed to underpin these empirical findings.

For practical use in policy making, the Y-factor may be used as a "quickscan" for further analysis. This is not unlikely, as various nations have tens of abatement options (not just six) and this method provide a structured and transparent way of justifying the need to research some cases even more in-depth.

4.5 Interim conclusion

Chapter four began with the question of "How to compare the abatement options by means of the Y-factor". To answer this question, four comparison exercises are performed in this chapter.

In section 4.1, the six case studies are compared and similar data is found by looking at the qualitative data of each case separately and holistically. In the quantitative scores, the observations do not perform out of the ordinary, and in the qualitative narratives underlying the scores seems to have some patterns. In section 4.2 the categorical narratives are examined, and the found patterns in the data are compared with transition theories. Also the expectations of transition theories are also compared with. Two categories are found to be compatible with transition theories. The patterns found in the Cost and Finance (C&F) and the Multi Actor (MA) category, respectively the four stages of business cases and the multiple perspective and the actor constellations, can be reconciled with in transition theory. The patterns for Physical Interdependencies (PHI) and Behavior (Beh) could not be reflected with transition literature. In comparing the expectations of the 13 subfactors, a majority of the expectations (8 out of 13) was observed in the six cases. In section 4.4, the cases from three types of interviewees (Stakeholder, Knowledge and Government) are compared in the perspective analysis. It is found that the Knowledge and the Government perspectives are similar, while the Stakeholder perspective is significantly different. The Stakeholder perspective might overestimate PHI and also C&F, but may underestimate MA. However, the data here is too small, and may only serve as additional nuances along with case conclusions. Last, but not least, in section 4.5, the Y-factor is compared with the MACC. First a comparison with a simulated MACC, and second with the reconstructed MACC from the industry report. The first comparison with the simulated MACC, showed that some cases are may be more likely to be explained by the Y-factor than with the more economic MACC. However, it should be noted that some cases showed that the MACC would likely to have more explaining power than that of the Y-factor. The Housing case is most apparent with the former finding of the comparison with the MACC. However, the Forest case may be better explained by the MACC

factor. In the second comparison with the reconstructed and oversimplified MACC from the industry report, the Housing case also suggests that the Y-factor would perform better than the MACC. Three additional findings can be mentioned, the Forest case is now inconclusive, as it is scored low in both the Y-factor and the MACC curve. The Green Gas case now may be better explained by the Y-factor. For both the Wind and Waste case, the MACC would perform better.

In short, to answer RQ3, abatement options can be compared with by means of the Y-factor in four different ways. The data derived from the Y-factor, and the qualitative empirical evidence shows that the data retrieved was comparable, and some can be reconciled with transition theory. A majority (8 out of the 13 subfactors of the Y-factor) of the expectations derived from transition theory were also met in the observations. Moreover, a comparison was made between three different perspectives for the cases. Last, but not least, the Y-factor has been compared with the MACC, and some interesting findings can be found for the six cases and may be used as a quick scan to determine whether evaluation methods such as the Y-factor or the MACC could be used by policy makers.

5. Conclusion, discussions and recommendations

"No matter how many instances of white swans we may have observed, this does not justify the conclusion that all swans are white."
Karl R. Popper, 1959

"A stupid man's report of what a clever man says can never be accurate, because he unconsciously translates what he hears into something he can understand."
Bertrand Russell, 1945

"Promises can create hope, but unfulfilled promises can lead to disillusionment and frustration."
Pressman and Wildavsky, 1979

5.1 Conclusions

The main research question of the thesis is: How can the Y-factor contribute to the understanding of the CO_2 abatement options? This question is answered in three parts:

RQ1: How does the Y-factor relate to theories, more specific transition theories?
RQ2: What is the applicability of the Y-factor on a variety of CO_2 abatement options?
RQ3: How can CO_2 abatement options be compared by means of the Y-factor?

First, the rationale for transition theory is derived from perceiving the abatement options as subsystems in the wider climate system in transition. The policy challenge then is to move the climate system from a high carbon-based economy to a low carbon-based economy. The Y-factor suggests that multi actor, physical interdependencies and behavior factors could play a role in the implementation of abatement options. Under the assumptions of these starting points, a model is missing that would describe the challenges of such a movement from high to low situation. Theories from transitions and transition management (TM) may help in describing such a movement to low carbon economy and thereby relate the Y-factor.

From a TM perspective, the Multi Actor (MA) of the Y-factor could relate to the Multiple Level Perspective and Transition Arena. According to TM, relevant actors exists in three levels, niche, regime and landscape level. Niche refer to the niche-players, they are the frontrunners in their field, the frontrunners of technologies, the visionaries. They can either be individuals, groups of engineers, entrepreneurs or organizations. The regime refers to the current incumbents, institutions and large organizations, who share routines with each other's. Regimes are fairly stable and is not governed by a single actor, however a regime might strike back. As niches may breakthrough the regime level and disrupt the stability and the status quo. The landscape level is at the macro level. This level is typically slow and may enforce pressure on the regime, which in turn may create opportunity windows. The Physical Interdependencies (PHI) of the Y-factor could be related to TM, because abatement options

can be seen as a subsystem, and because other subsystems exist in the entirety of climate system, abatement options may therefore influence other subsystems, but abatement options may also be affected themselves and may be embedded in certain crucial dependency. Disturbance may therefore be understood as disturbing the daily lives of someone in the direct vicinity or someone far away, especially at times of implementation. Embeddedness refers to the existing systems, and subsystems, such as being dependent on the existence of the road or power grid infrastructures, or certain geographical features among others. From a TM perspective, technologies and the experimentation with technologies in the market are important drivers for transitions. Crucial technology may still be in R&D stage, and the Y-factor notion to assess 'technology uncertainty' makes sense. For the Behavioral (Beh) factor of the Y-factor, TM may relate the efforts of individuals, the society and its aggregated and collective action to the Beh category of the Y-factor. Transitions involves large behavioral changes. Experience in similar events may help. Behavioral characteristics of being entrepreneurial, being in a culture of stepping out of the comfort zone, and having the habit and opportunities to think outside the scope helps too. The Cost and Finance (C&F) of the Y-factor is somewhat unrelated to TM. Transition Management is about creating the right market conditions, and creating a level playing field for the niches and the regime. Individual projects do not matter, the aggregate of projects that drive the transition matter.

From a high level perspective, the Y-factor can be related to TM. However, only the MA category is strongly related to TM, followed by both PHI and Beh, and then C&F. In the thesis, this can be seen in section 4.2 when the cases are compared with theories and with the expectations for each of the 13 subfactors derived from theory.

> Conclusion 1: The literature on transition management is helpful in relating the Y-factor with important theoretical concepts. However, important notions seems to be missing in transition management to relate to the whole Y-factor. More specific, the Multi Actor category seems to be sufficiently relatable, while the Physical Interdependencies and Behavior category required disproportional efforts to relate to transition management.

For **RQ2**, this thesis has applied the Y-factor to a variety of abatement options. Six cases studies are created from six different sectors are studied using the Y-factor. For the case study, primary sources are used, and collected via face to face semi-structured interviews. The Y-factor is used as an assessment framework during interview, and general principles for conducting good semi-structured interviews are followed.

	1	2	3	4	5	6
Sector / domain	Heavy Industry	Built Environment	Energy Production	Forestry	Agriculture	Waste
Abatement option	Carbon Capture and Utilization	Heat and energy refurbishment for Housing	Extra wind farms at Sea	Afforestation of 100k ha	Biogas and Green gas installations	Carbon capture for waste incineration plants
Case code name	CCU	Housing	Wind	Forest	Green Gas	Waste

A total of 21 interviews were carried out and the Y-factor showed that not only in-depth case studies can be developed, but that interviewees are generally engaged and that interviewees understood the Y-factor and the need for such a study. Last, but not least, the Y-factor helped in creating a feeling of a common understanding in the interviews. For almost all interviews, a constructive dialogue is formed from the perspective of the interviewer. The interviews did not feel like a monologue.

> Conclusion 2: The Y-factor may be applied to abatement options in the sector heavy industry, built environment, energy production, forestry, agriculture, and waste,

because useful case studies can be constructed with the retrieved data and because the Y-factor was found to be an empowering tool for creating constructive dialogues in the interviews.

For **RQ3**, and its question of how to compare CO_2 abatement options using the Y-factor, four comparisons were made. First, the quantitative scores could be derived from the case, using the Y-factor. The narrative constructed for each category of the Y-factor, could also be used for a qualitative comparison. Second, the qualitative comparison showed that interesting patterns could be identified. These patterns are compared with theories from transition management. At the same time, a comparison is made between the expected scores based on the transition theory and the actual scores based on the observations. Third, three types of interviewees are defined in the data, and the Y-factor scores are compared from the perspective of the Stakeholder, Knowledge Organization, and Government. The data shows that the Knowledge and the Government perspective is fairly similar to each other, while the Stakeholder is somewhat different from the two. Last, but not least a comparison is made between the Y-factor and the MACC. In this comparison, it can be said that the Y-factor may be complementary with the MACC. The comparison shows that some cases may be more suitable for the Y-factor than for the MACC. However, the reverse is also true, in some cases the MACC is more suitable than the Y-factor. The empirical data suggests that the Housing and the Green Gas case may be more suitable for the Y-factor.

Conclusion 3a: The Y-factor can be used to compare between abatement options. Results from multiple comparisons show that useful patterns can be identified between six cases of abatement options. Some of these patterns can be explained by transition management theories.

Conclusion 3b: The methodological comparison of the Y-factor with the MACC shows that the Y-factor can act as a complementary tool to the MACC. In this comparison, the Y-factor may either increase or decrease the rationale for a MACC analysis for a given set of abatement options. The Y-factor may also be neutral about a subset of abatement options. In the case of a decreased rationale for the MACC analysis, the Y-factor encourages the use of other non-economic models.

To conclude for the main research question, the Y-factor has been studied in the context of transition and transition management theory. The descriptions and explanation given of the Y-factor were tested in the Dutch context with a variety of abatement options. The collected data showed that the Y-factor is applicable in understanding, and creating single case studies of abatement options. The single case studies were also applicable for multiple case studies, as the Y-factor provided enough structure. The findings of the multiple case study comparison showed interesting patterns in the observations and some of these observations can be reconciled with transition management theory. In any case, the comparison of the abatement options using the Y-factor and the MACC showed that the Y-factor could be complementary to the MACC. Empirical evidence suggests this for the Housing case, and in a less probable sense for the Green Gas case. The same empirical evidence suggests that the reverse can be concluded. The findings suggest that some cases may be better suited for the MACC, such as for the Waste, Forest, and the Wind case.

5.2 Discussions

5.2.1 Discussion of findings from a literature perspective

The conclusions drawn for each of the research questions need to be put into a wider literature perspective. First from within the transition literature perspective, second from a wider economic perspective, and third from a wider societal perspective.

First, transition theory has been extensively used in answering the research questions. However, only a select collection of the whole theoretical field that is found for transitions in literature is used. A certain search methodology is used, and only a specific subset of transition theories is found. As mentioned earlier in section 2.1, transition from a more organizational perspective has been left out. In Chappin (2011) several levels or scales of hierarchy has been defined in which transition can be researched. In this hierarchy, transitions may be researched at the global, national, sector, organization, individual, cell and atom scale. In this thesis, the selected literature of transition can best be appointed to the sector scale, but abatement options from an organizational perspective may just as well provide valuable insights. The rationale for this may come from the data in this thesis; various organizations has been found to be detrimental in driving one of the six abatement options and thereby useful for the assessment of abatement options. In selecting "transition theories" at the sector scale, other transition theories may be relevant too. For example, de Haan (2018), in which the author has a strong system learning focus on transitions in sectors. In her book she defines three levels of system learning; transformational learning, learning with Theory U and creative learning. This suggests that this the superset of transition theories in which this thesis made a selection of is too narrow, as transition theories on the same sector scale may be enriched with insights from such a system learning focus.

Second, the Y-factor may be studied from the perspective of non-transition theories. Due to the strong focus of the Y-factor on the MACC and the problem scope of the Paris Agreement and the agreement's goals to move to a "low carbon economy" or to "decarbonize the economy", the climate problem has been scoped as "transition". While a rationale has been given as why this may make good sense, other conceptualization of the climate problem may be just as rational.

In the preliminary desktop scan, as mentioned in section 1.5 and in Appendix B, several scientific fields has been put forward as alternatives to traditional economics and thus as candidates for the Y-factor. For example, *behavioral economics,* with an origin in psychology and cognitive science, and *new institutional economics*, with an origin in property rights, game theory and transaction cost economics among others. The theories from behavioral economics may be a better fit for explaining the Behavior category of the Y-factor. In behavioral economics, key concepts such as heuristics and nudging may give the Y-factor a different meaning and the Paris Agreement and its abatement options may be perceived differently. For example, the abatement options may be perceived as nudges to induce a citizen-wide societal change. The approach would be to identify existing heuristics in abatement options and nudge them in such a way that individuals would adopt CO_2 sensitive heuristics. From a new institutional economics perspective, the goals of the Paris Agreement may be seen as a the result of various institutions of power at play. The focus may then be on institutions and the design of interactions and governance arrangements for the market in which transaction costs may be minimized for abatement options. The categories of the Y-factor may then be explained as functions of transaction costs. The embeddedness and interactions in the Physical Interdependencies may be better explained with concepts like transaction costs. The empirical data in this thesis, supports additional theories for the two categories, however, the two economic concepts here serve as illustrative suggestions. In these two examples from outside the transition theory field, the notion of transition is not as apparent, and these alternative economic concepts may better explain the abatement options.

Third, the findings and conclusions of this thesis are entirely based on research in the Netherlands. This suggests that the conclusion may not be transferable to another country without further examination. Cultural aspects may play a role, but geographical characteristics may play a role among others. Two examples can be given, one from within this thesis, and one external to the thesis. One of the comments in the Waste case indicate that the Norwegian carbon capture installation serves as an example and can be seen as success stories to be learned off. The exact reason as why Norway holds this leading position for carbon capture is

said to be guesswork by the interviewees. Some interviewees comment on that it may be due to the legacy that waste plant are 100% owned by the state or that it is because of the favorable geographical location, or due to both. In the book *Guns, Germs and Steel* (Diamond, 1997), the author attempts to explain why some civilization survived and thrived against others. The main argument is that gaps in technology *and power) originate primarily from different geographical and environmental conditions. The theory is that geography has been the largest influencer. However, this geographical theory is both loved and criticized in and outside the academia, but it acts as a signal as why it is important to be aware the country's context.

5.2.3 Discussion of limitations of the research perspective

The findings of the thesis has been derived from the research perspective that the climate and its abatement options can be perceived through the systems perspective. The assumption of the systems perspective can be shortly explained by an analogy. It may be said that the systems perspective only makes a snapshot of the current situation, in the sense that a snapshot is framed and encapsulated in one moment, and therefore necessarily incomplete (Enserink et al, 2009). In reality, the implementation issue of CO_2 abatement options is more complex, but through the lens of systems perspective it is simplified by creating a snapshot of the situation. This has advantages, as the snapshot approach or the systems perspective makes it possible to analyze the situation in detail and make a comprehensive model of the reality. However, scholars should not strive for a complete and realistic model, rather a good model that fit the problem at hand. Much time, and (human) resources is needed for recreating the reality, Herbert Simon (1991) speaks of "bounded rationality". Moreover, scholars argue that this type of reality is not desired most of the times anyways. Scoping decisions are therefore important, and making these as explicit and transparent as possible is even more crucial. The rationale for assuming "bounded rationality" in the first place is that in practice, abatement options are problems of the society, and that such policy problems do not get decided overnight, or within a short time. Policy problems are long term problems, and may even change and evolve over time. It is important to be aware of this limitation of the systems perspective.

A second limitation of the systems perspective is that the analyses may depend on the eye of the beholder, or the problem owner. While system analysis may be done for multiple problem owners, it is not specifically developed for such environment (Enserink, 2009). System analysis is an approach that grew out of the operation research and knows its origin at the RAND Corporations (idem). Other methods are needed to create a more representative system analysis. The authors from Enserink (2009), suggests that for the short/long term limitation, the discipline of creating scenarios and futures should be considered. For the limitation of multiple problem owners, the discipline of actor analysis should be considered.

In this thesis, the perceived problem owner of the Y-factor is that of a national CO_2 policy maker. However, the policy instruments of this problem owner have not been examined. Only the wider decision making context of the MACC is analyzed. To compare, the MACC can be seen as an evaluation method or a prioritization tool for abatement options. When options are economically hampered on the basis of the MACC analysis, economic measures may be considered, for example tax incentives or subsidies. However, for the Y-factor, the focus is on non-economic factors. The thesis has not looked at what other policy instruments may be relevant and which policy instruments may be more effective or efficient. The findings of the Y-factor in this thesis may therefore only have implications for the policy makers deciding over MACC analyses among other abatement options analyses. The findings of this thesis, has no implications for the analysts of the MACC.

5.2.2 Discussion of methodology limitations

Limitations of the data collection method

The thesis based its analysis on data collected from interviews. Several limitations can be mentioned, for example knowledge/jargon gap, self-reported bias, poor interview skills or inefficient skills, among others (Adams, 2010; University of Southern California, 2018).

An example of the knowledge gap of the researcher for this thesis is apparent in the Green Gas case, one of the interviewee has worked for the sector for tens of years, and is recently primarily involved in bio and green gas. When asked a question about the Y-factor, more specific the interdependencies and disturbance questions, the interviewee understood the question, but I didn't understand his answer. In the audio recordings, I found that I have tried to ask follow-up questions, but it was apparent that there is a knowledge gap. In the recordings, I have noticed myself noticing that asking more questions could hurt the interview process. I noticed that I choose a good process of the interview instead of a clear answer.

An example of self-reported bias, may be found in the Y-factor questions which require an estimation of a quantity, such as is it many, medium or few. This bias may be specifically useful for further research with the Y-factor. Quantitative estimation on the spot, may depend on the interviewees' memory. This may be selective and subjected to an exaggeration or an understated bias. Sometimes when I ask the "how many"-question, the interviewees would make a list. The concluding answer for the question seems to steer to many or much, when making a verbal list. When interviewees would write them down, it would seem to be less. More data is needed to support this though.

An example of poor interview skills is that I find myself not always 100% consistent in asking the questions. Be it another sequence, or just not using the same words when I start a question. For example, I found myself to be asking for "important actors", "most dependable actors" or "actor dependencies", instead of being consistent with one phrase.

Limitations on the selection of interviewees

Methodological limitations reside within the selection of interviewees for the interviews. The semi-structured approach requires experts, or policy makers, with a certain involvement to the abatement options. It is sometimes hard to assess in what way the interviewees are exactly involved, especially before conducting the interviews. Four methods are used for a more careful consideration of selecting the interviewees: 1. The Triple Helix approach for innovation for the variety of interviewees in the six selected cases of abatement options, 2. Identification of experts through authorship on related white papers, industry reports or governmental documents or websites, 3. Exploration of personal information of the interviewees and 4. offer email or telephone correspondence before the actual interview.

The rationale for the Triple Helix is explained in section 2.2.1. However, the decisive argument may be simply a practical one. In TM, various types of actors are mentioned, such as frontrunners, ministers, pioneering individuals, but also less high-level individuals, such as some generic types of actors, i.e. "engineers, societal groups, scientist, users and policy makers" (Geels, 2004, p. 900). While these types as candidates for multiple perspectives may require extensive time and resources, the argument for why two perspectives are not chosen, or why a Quadratic Helix approach (Celiktas & Kocar, 2009) is not chosen, is lacking. In another study (Rikkonen & Tapio, 2008), the interviewees are selected on the basis of three dimensions; the expertise dimension, the dimension of the studied themes, and the dimension of the technology chain.

In step 2, the initial identification of interviewees, the approach is to contact authors of project reports and white reports from governments and industries. Here a certain level of expertise and involvement to the six abatement options is assumed for the authors of the reports. However, other criteria may be used for selecting the, such as using the levels of 1. unfamiliar 2. accidentally familiar 3. familiar 4. former expert and 5. expert, from Enserink 2009) adopted from Loveridge (1982). The limitation is that a framework of "high involvement

of interviewee" is not further sought. The different between an expert and the informed layman (Kripke, 1973) or the overconfident ignorant experts (Bradley, 1981) are not studied. Other methods of contacting interviewees may be through recommendations from experts in the field, or creating a call to respondents or an advertisement at a topic related organization or platform. Aside from the scoping decision made in chapter two, a comparison for the best selection method for the interviewees is lacking. In step 3, a persona analysis is done, but likewise, not framework is used for controlling for the expertise of the interviewees, and no interviewees were dismissed at this stage.

In step 4, an invitation to ask questions via email or by phone is added at the email invitation. Most interviewees sought out clarification after receiving the invitation email. Some interviewees did this via telephone. Personal bias, poor follow-up skills, and poor expectation management may have influenced the selection or the consequent quality of the interview.

Limitation of the Y-factor as a tool for semi-structured interviews

The fourth limitation is my interpretation of the Y-factor assessment framework. While research question one revolves around making an interpretation of the Y-factor framework, some interpretation changes along the thesis process should be noted. I have reversed the order of question 4 and 5 of the Y-factor. I found this to be more logical after one of the first interviews. It felt more logical if I would go from abstract and high level to a more concrete and low level. Especially, when I used words such as "helicopter view", and "geographically" for the "number of actors" questions. Another adjustment to the Y-factor is the question regarding "out of scope". The question is framed as a "surprise" question. This actually has limited alignment with literature, and is derived from my own interpretation of the transition theory.

Sometimes when collecting data from the interviewee, the interviewee tries to fill in the assessment framework themselves. However, I have chosen to decline this and do this myself. I find this more logical as the framework is mostly for opening up dialogues, and it is about my own interpretation of said comments in the end. This limits the interviewees to be more involved in the Y-factor. This is initially chosen due to the expected unfamiliarity of the Y-factor for the interviewees. The expectation is that a majority of the interviewees would be unlikely to be interviewed if there is high "workload" on the interviewees.

Limitation of the Y-factor scores

The scores of all six case studies are mostly given by the interviewees themselves, however some scores are my own interpretation of the answers and comments given by the interviewees. This happened, because in practice the questions faced difficulties when collecting a conclusive rating on the 13 question. Some interviewees may be hesitant in given such a narrow answer, and more are comfortable if this is done by myself and noted as such, so the interviewees wouldn't have to do the simplification. This result in some bias or uncertainty in the scores. In the 13 scores, the uncertainty of each for each case are not assessed. In chapter three, the six cases are assessed in their applicability. In this assessment, three criteria are used: 1. level of understanding, 2. usefulness for case study, and 3. level of constructive dialogue. In concluding section 3.7, the six cases have been assessed in these three criteria. While each uncertainty level of the 13 scores of the Y-factor cannot be given, the overall uncertainty of the Y-factor may be compiled using these three criteria. The rationale is that these three criteria may be a signal for the uncertainty of the Y-factor as a whole. Other scores for the Y-factor may be more suitable, such as the Likert scale (Boone, 2012).

The last point in discussing the scoring process is that some questions brought comments that cannot be placed in the Y-factor. For example, the "type of actors" question in the Green Gas case, resulted in comments about "people not knowing where food comes from anymore", indicating a divide of the rural and urban, or comments about another transition (e.g. Circular Economy). These comments indicate a political or societal sentiment and interactions with other transitions. In reviewing the transition literature, few comments can be found, and further research is needed to put this in the context of the Y-factor.

5.3 Recommendations

This thesis has mostly conclusion for the Y-factor as a method. The conclusion has limitations, and further research may therefore be needed. Based on the limitation discussed in the previous section, this final section provides a list of directions for further research.

5.3.1 Directions for Y-factor research

This thesis only explored parts of the transition literature for the Y-factor. Two recommendations can be given, one within transition theories and one outside transition theories.

First, one recommended direction for research for the Y-factor from within the transition perspective, is research on a lower scale: namely the group scale, and the interaction between this group scale with the sector scale. In the examined transition theory, the Transition Arena consist of 10 to 20 individuals, a group or a team. The arena is formed between individuals, of which their respective organizations may have never worked together before. However, in the transition arena the players are required to operate at the strategic, tactical and operational level. Moreover, the transition arena need to go a process of evaluating with an independent panel of experts over time. Key notions here are “learning-by-doing” and “doing-by-learning”, (Loorbach & Rotmans, 2006, p. 197) which imply heavy learning processes. De Haan (2018) proposes to take a more in-depth look at learning processes for transitions, but more specific at “system learning”. De Haan (2018) discusses three levels of learning, and may complement the key notions of “learning-by-doing” from a more group scale by focusing on the transition teams in cases like a corporate company (Phillips), an agricultural foundation (Stichting Veldleeuwerik) a health cooperation (Stichting IZZ). The cases are Dutch cases, and on the basis of this thesis, a similar look at the Y-factor from this group scale may help in understanding why certain abatement options may succeed or fail.

Second, from outside the transition perspective, it is recommended to study the Y-factor from a behavioral economics perspective. In the book “Nudge” by Thaler and Sunstein (2003), the term nudging is introduced as a mechanism to influence behavior but without coercion. Nudges are interventions that are easy and cheap to avoid, however they are not mandates. In Benartzi et al. (2017) nudges are researched in the policy domain. Nudges as mechanisms may be interesting for the categories of the Y-factor. More specifically, a recent study (Mastop et al., 2017) in the context of behavioral and organizational behavior has been conducted in the Housing sector in the Netherlands by ECN, a research institute. For more specific sector level research, a behavioral study for each of the six case study in this thesis (or other sectors) is recommended.

5.3.2 Methodological recommendations

In fitting any theoretical notions for the Y-factor, recommendations can be made on the methodology in doing so.

First, for the limitation of the selection of interviewees, and the limitation of the systems perspective in the sense that abatement options are ongoing and dynamic phenomena, it may be recommended to conduct a Delphi Study (Bell, 1997). A Delphi study also make use of interviews, but is more structured. It also uses multiple rounds of interviews. The interviews may be send digitally. Moreover, the Delphi method involves a larger group of experts. Each new round includes intermediate analysis and aggregation of the answers of the previous round. Each round has a specific aim, for example exploration, prioritization and adjustments, and lastly convergence or consensus. This process may repeat more than 5 rounds. In this thesis, have only conducted one round of interviews is carried out. The disadvantage of the Delphi method is the long run time, and that substantial organizational power is needed for setting up and maintaining the whole expert group. The Delphi method may also be less suitable for explaining why abatement options do not material, but may converge on the Y-

factor from a descriptive perspective and assess the abatement options in the characteristics of the Y-factor. The result of the Delphi study may act as an evaluation or monitoring tool.

For the first round of researching different levels of expertise, the five levels of expertise from Enserink 2009) adopted from Loveridge (1982) may be compared with other frameworks. For example the levels of “none, interactive and contributory” by Gorman (2002), or other definitions of basic, intermediate and experts levels in the discussion of the eye of the bolder in Tanaka & Taylor (1991).

Lessons can be learned from studies such as Jittrapirom et al. (2018), in exploring the future prospects of mobility as a service through three rounds of interviews. Respectively in the first, second and third round, 89, 49 and 35 experts were interviewed. The future prospect of alternative bio-energy use in Finland, was assessed through 20 experts in the first round, and then 18 experts in the second round (Rikkonen & Tapio, 2009). A foresight study of Turkey’s renewable energy (Celiktas & Kocar, 2010) is assessed through 382 respondents in the first round and 325 in the second round.

A suggestion for the first round of the Delphi method, may be the research into specific levels of expertise may be the aim. The multiple round structure of the Delphi method may also add on the limitation of the systems perspective of too short term focused and by being not intertemporal.

Extending the cases for building up the empirical evidence for the Y-factor will help underpin the Y-factor as a complementary tool to the MACC. A direction for further research may begin by using Chapter 3 and 4 as inspirations for future labels and parameters for a more quantitative study of the 13 subfactors of the Y-factor. In line with this, a possible future analysis may be a statistical method. In redesigning the subfactors into useful labels, for example an ordinal label by using Likert-scales. This method may measure attitudes of interviewees towards the 13 subfactors, in doing so another type of empirical evidence can be build up for the Y-factor. Quantitative analysis, such as the Factor analysis, a type of multivariate analysis (Bartholomew et al., 2008) may be relevant for further analysis. Additionally, the analyses may result in correlations with the factors. It would be interesting to see how the results would compares with the MACC.

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Appendices

Appendix A – Similar presentation method of the Y-factor and the MACC

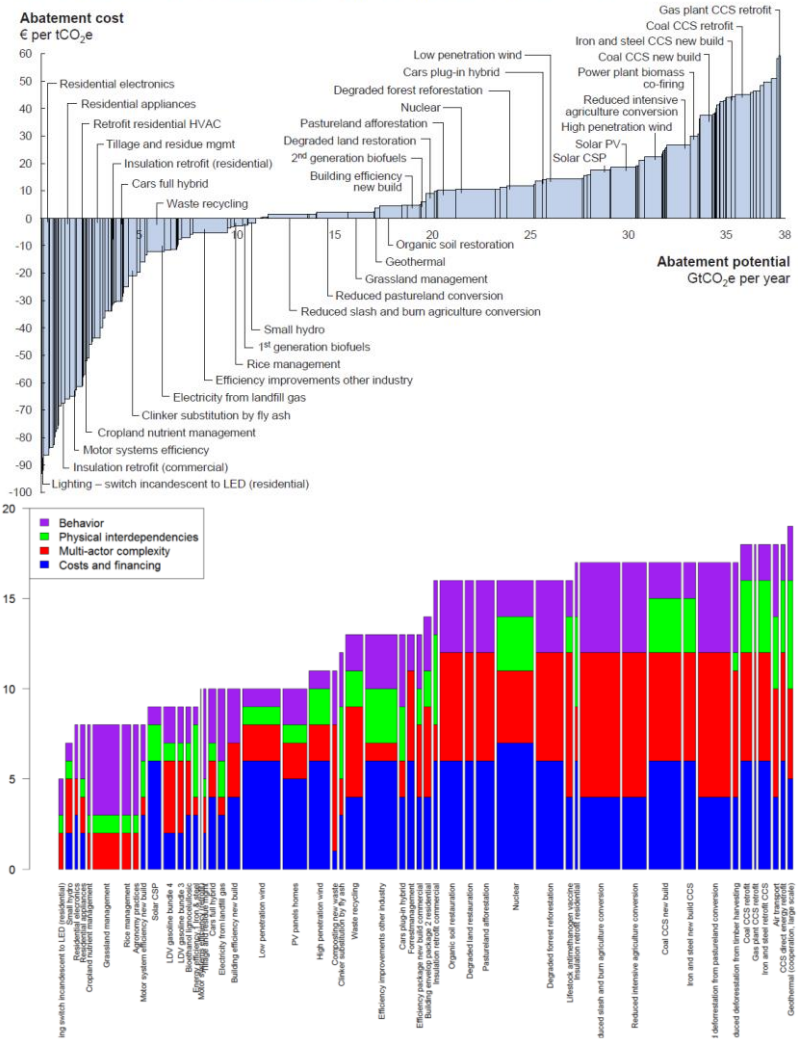

Figure 24 – The MACC and the Y-factor curve

In this appendix, two graphs are being compared on their data presentation method. The first graph is the Marginal Abatement Cost Curve (MACC) and the second is the curve constructed using the Y-factor. The similarities are threefold:

- A variety of abatement options are analyzed in a level of "cost", whether it is in euro's as in the MACC, or in a variable without unit. The implication of a high score is that the abatement option is less likely to materialize
- The abatement options are ranked from low to high starting from lowest on the left. They are prioritized
- The width of each abatement option may vary, and this the thickness of each bar represent the CO_2 potential. In the Y-factor curve, this is not written clearly, but it is incorporated.

Appendix B – Preliminary Google desktop research.

The following systematic approach is used for the preliminary desktop research. First the four categories are used as keywords, then a follow up keyword search. Based on the introduction, the following keywords as used: “Irrationality”, “barriers to implementation”, “non-economic factors”. For example, “behavior and non-economic factors” are googled. The 4x3 search returned many hits, these can be articles, white papers and scientific papers. Such a scan of popular literature may very generically explore why the four categories proposed are relevant to the Y-factor. The benefit of such a popular scan is that it is relatively quick and simple. The disadvantage is that it lacks a level of detail, important theories may be overseen and a personal biased may play a role in interpreting the search results. The personal biased played the largest role in selecting the relevant search results that are presented in table 26. Selected theories and concepts may be based on the familiarity of the curriculum of the university faculty and its course material. It is useful to note that personal selection bias is present.

Table 26 – Preliminary desktop search

Category	Follow up keyword search	Relevant concepts and theories
1. Costs and financing	a. irrational decision making	Sunk costs [1] and transaction costs theory [2], behavioral economics [3], behavioral finance [4]
	b. barriers to implementation	Financing barriers [5],
	c. non-economic factors	Land economics [6]
2. Multi-actor complexity	a. irrational decision making	Decision making [7], ”actors in network” theories [8], “complex networks” [9]
	b. barriers to implementation	“Multi-actor implementation” [10], transition management theory [11]
	c. non-economic factors	Multi-criteria decision analysis [12] “Social exchange mechanism”, “policy networks” and “alliance formation” [13] Rational Choice Theory [14] Bounded rationality [15] neoclassical economics [16]
3. Physical interdepen-dencies	a. irrational decision making	Ecological economics [17], infrastructural dependencies [18] New Institutionalism [19]
	b. barriers to implementation	Barriers to (climate) adaptation [20]
	c. non-economic factors	Levels of interdependencies [21]
4. Behavior	a. irrational decision making	Game theory [22], behavioral economics [23]
	b. barriers to implementation	Cognitive-Behavioral Therapy [24]
	c. non-economic factors	Non-economic factors [25], Sociocultural influences [26]

Appendix C – Review literature semi-structured interviews

The Advantages of the semi-structured interviews are: 1.focuses directly on case study topic, 2. provides perceived causal inferences. Disadvantages: 1. Bias due to poorly constructed questions, 2. Response bias, 3. Inaccuracies due to poor recall, 4. interviewee gives what interviewer wants to hear.

Table 27 – Review of three semi-structured interviews sources

Step	Authorized Professional Practice of the UK	Raworth et al. (2012)	Adams. 2010
#	**Nickname: PEACE**	**Nickname: Oxfam Guidelines**	**Nickname: SSI**
1	Preparation and planning	Identify the right people	Selecting Respondents and Arranging interviews
2	Engage and Explain	Setting up an interview	Drafting questions and the interview guide
3	Account, Clarify and Challenge	Skills for listening, understanding and questioning	Starting the interview
4	Closure	Themes for discussion	Polishing interview techniques
5	Evaluation	After the interview	Analyzing and reporting
Con-text	Investigative Interviewing in the domain of fraud and crimes	Semi-structured interviews for development research (Guidelines from Oxfam)	Semi-structured interviews for practical program evaluation (a handbook)

One of the first observation is that the three examined literature all have five steps or stages. This could be a heuristic that is just easy to remember, comparable to something like all good things come in three. Some of the steps contain and thereby implicitly hide 2 or more steps in one single step, such as “account clarify and challenge”. The fact that they come in five, could indicate that they may have learned from each other in some way. Regardless, there are similarities, but also quite some differences.

The second observation is that it is imperative to get familiar with the context in which these interviews steps are discussed. PEACE is a mnemonic for investigative interviewing, and aims to “improve the interviewing skills of the interviewer, both in terms of the standard of the interview and the quality of information generated from the interview itself” (Shawyer & Walsh. 2007, p. 107). The PEACE method encourages an open mind, fairness and a search for the truth, rather than a confession-oriented interviewing strategy. The Oxfam guidelines focuses on development research and provides a set of tips and techniques for getting the most from the conversation from semi-structured interviews. Such interview is presented as one of the best way for learning about the “motivations behind people’s choices and behavior”. In a more general article in the Handbook for practical program evaluation, SSI is discussed and placed in the context of other interview methods, such as the focus group and surveys. The articles first made use of the abbreviation SSI to differentiate itself from similar interview methods, such as “focused interview”, “ethnographic interview”, “depth interview” or “qualitative interview”.

In comparing the first step, the words and its descriptions see preparation and good planning as important. In the PEACE method, the emphasis is on the characteristics of the interviewee itself, creating an interview plan and practical arrangements. The Oxfam guidelines puts less emphasis on such planning, it does emphasize on finding the right

interviewee. Methods such as “snowballing” are mentioned and talking to and making a key informants analysis are mentioned too. In SSI, the interviewee should be prepared as well, but cold calls should be avoided, and key stakeholders are mentioned too. If possible, the best way is to get to interviewees is through a letter of introduction.

In the second step, differences can be seen. While the PEACE method focus on engaging and explaining the interview and its questions, the Oxfam guidelines and SII are still focused on preparing the interview. In step 3, the PEACE method and the Oxfam guidelines seems to overlap. The role of open-ended and closed questions are discussed and the importance of interview skills is discussed. This step seems to overlap with step 4 of SSI : Polishing interview techniques. Here similar notions are given, that questions in itself are not enough. The interviewer needs to clarify and challenge (PEACE), listen, probe, and be aware of sensitive topics (Oxfam guidelines) and “prompting respondents to elaborate” in various ways (SSI). In step three, the SSI elaborates on the importance of the first impressions, the considerations needed for to record or not to record, and taking notes and addressing the matter of confidentiality. In step four of PEACE and in the Oxfam guidelines, the interviewer should summarize the interview and discuss some practical matters of what to happen next. In the Oxfam guidelines, the interviewer is reminded about the themes to cover in an interview guide, and about some practicalities, such as local units and also leaving room for questions and has been recorded on paper so far. Step four of SSI is already discussed earlier. In step 5, the interview has come to evaluation stage, and the focus is on knowing what to analyze in the next steps, and how it is helpful if the interviewer knows this beforehand and at the time of the interview. This could be a written statement, notes, stories, summarizing key notions and comments, or conduct a qualitative data analysis with additional software?

In conclusion, the general notion is clear: preparing an interview requires several steps. Several techniques has been discussed for finding the right interviewees. An interview guide, note, or template is imperative and should be created to stay on course with the research questions, but also as a fallback sheet when actually conducting the interview. In this guide, the questions can be open-ended but also closed-ended. The interviewer should have neutral and unbiased questions, and should aim for first questions to be more open and general, but have another set of follow-up questions with more specifics. Questions should be checked before on its possible answers on known websites or other sources. If the questions are found to be too descriptive, reformulate and check whether they still comply to answering the thesis.

Appendix D – The interview guide

In figure 25, an example of an interview guide can be seen. The profile of the specific interviewee has been left out. The example is derived from the Housing case, as the "sustainability in dwellings" might suggests. As one can see, the interview guide consists of three parts. With the third part being an extra printed out Y-factor assessment framework in a more tabular form in figure 26. All interview are accompanied with the interview guide printed out in A4 and the assessment framework printed out bigger in A3 in color.

1. Introduction

1. Motivation
   - Expertise in the area of **sustainability in dwellings** in terms of energy efficiency. Also, I have been recommended to you by my first supervisor: Emile Chappin.
   - Focus on the relation between the "built environment sector" in regards to the "national" emission targets (very narrow view).
2. Profile Interviewee:
   - 1
   - 2

2. Project description

- **Scope**: Not one project or program, but the nationwide ambition to renovate housing to be more energy efficient. It could be the thousands and the millions of households. To reduce the energy (gas) use). To my understanding, this can be done in generally two "technical ways": isolation and installations. Isolation: gevel, vloer, glas, dak. Installation: **boiler, heating and warm water**, and air, and newer ones: solar boilers, and PV-cells.
- **Time**: continuous process of energy saving and thus CO2 reduction measures. Ambition of cabinet now: 30-50k existing households gas-free upcoming 4 years. Longer term goal is 200k housing per year, to fulfill 2050 goal of 6 million existing housing. 2-3 Mton feasible if 1-2 million household renovated, if they are "all-electric" or use district heating (with non-fossil).
- **Involved**: individual households, housing corporations, local and regional energy collective.

3. Research framework

- Email: complex, explorative in nature. Insights into non-economic factors
- With a transition theory perspective. Result in 4 themes of questions:
  1. Cost and Finance and their drivers
  2. Actors, key types, forgotten and clarity.
  3. Physical technological dependencies
  4. Behavior and behavioral change

Figure 25 – Example interview guide

Y-factor	Y-factor	Case questions	Leave empty for printout: Case name: Smart CO2 grid	Invullen
Kosten en financiering	1. Kosten (CAPEX / OPEX)?	1. Could u tell me something about the cost structures of these projects ?		Afwezig Medium Groot
	2. Payback period?	2. What can be said usually about the payback time?		< 5 yr 5-12 yr > 20 yr
	3. Financierings drempels?	3. How hard is it to finance CCU/CCS?		Geen Medium Groot
Multi-actor systeem	4. Hoeveel partijen, partners, belangrhebben zijn er betrokken?	5. In such a CCU project, how many people could be involved ?		Weinig Veel Miljoenen
	5. Afhankelijk van de betrokkenen?	4. How many parties could the project be dependent on?		Geen Weinig Veel
	6. Zijn er type (conflict) partijen te onderscheiden?	6. How many types of actors can we distinquish? that have very opposite interests.		Laag Medium Veel
	7. Duidelijke rollen?	7. Are roles and responsibilities clear in such projects?		Duidelijk Beetje Onduidelijk
Fysieke onderlinge afhankelijk-heid	8. Ingebed of fysiek verankerd?	8. How embedded is a CCU project in its environment?		Niet Medium Sterk
	9. Storing dagelijkse operaties?	9. How will, in times of construction/transitin, the project cause disturbence to other daily business/operations?		Niet Medium Veel
	10. Technologie onzekerheid	10. What can we say about the uncertainty of the technology?		Bewezen Klein Groot
Gedrag	11. Outside the thinking scope	11. Could you imaging that parties would be somewhat surpised by the mentioning in the Regeerakkoord?		Niet Gedeeltelijk Buiten
	12. Kansen regelmatig	12. Do certain opportunities come often in the industry?		Vaak Medium Zelden
	13. Gedrag verandering	13. For the end-users, what could possibly change in their behavior?		Nee Beetje Groot

Figure 26 – Y-factor as an interview assessment tool

Appendix E – The email invitation to interviewees

In this appendix, the email template is shown. The template is in Dutch, as all invitation are derived from this email template. One email invitation was done in English. I will use the English email to explain the email invitation in four parts:

Beste [....],

Kort en duidelijk de uitnodiging tot interview + aanleiding (case specifiek)
VB: Graag zou ik u willen uitnodigen voor een interview in het kader van mijn MSc onderzoek. De aanleiding hiervoor is de Prefeasibility studie van de CO Smart Grid. Naar mijn bevindingen, is CCU een van de belangrijkste maatregelen van het regeerakkoord voor de klimaatdoelen, en wil hierbij in deze context een aantal open en gesloten vragen stellen.

Mijn onderzoek "teaser" (generiek)
Mijn onderzoek richt zich op CO2-reductie projecten. Het uitgangspunt is dat zulke projecten complex zijn. M.a.w. dat er non-economische factoren een rol spelen bij het realiseren van die projecten, en daarmee een effect hebben op emissiedoelen. Het doel van dit onderzoek is om meer inzichten te krijgen in de factoren die een rol spelen vanuit een aantal theorieën. Voor het precieze onderzoeksraamwerk kan ik nog een vervolg email sturen, maar ik kan ter zijner tijd ook een mondelinge toelichting geven. De uiteindelijke uitkomsten van mijn thesis deel ik uiteraard graag met u.

Mijn credentials (generiek)
Ik doe mijn afstuderen in het kader van het curriculum van SEPAM aan de faculteit van "Technology, Policy and Management" te TUDelft. Mijn 3-koppige afstudeercommissie bestaat uit: Dr. ir. Ivo Bouwmans (hoofd van de commissie), Dr. ir. Emile Chappin (1e begeleider) en Dr. ir. Els van Daalen (2e begeleider). Het uiteindelijke doel van de interview is om een bijdrage te leveren aan de wetenschap. Het interview zal niet voor andere (publieke) doeleinden gebruikt worden.

Afsluiting + praktische zaken (generiek)
Het interview duurt ongeveer 1 uur en ik wil graag met u een afspraak maken een dezer weken. Ik hoop u voldoende te hebben ingelicht en hoop snel van u te horen. Hierbij mijn telefoon voor eventuele vragen en afstemming: 0614695594 (ma-vrij).

Met vriendelijke groet,

Chun-Yu (CY) Cheung
MSc student Faculty of Technology, Policy and Management, TU Delft
M: +316-14695594 (ma-vrij)

Figure 27 –Template of email invitation in Dutch

1. The Motivation and formal interview invitation (case specific)
    a. Freely translated in English: Hereby I would like to invite you for an interview in the context of my MSc research. The motivation for this is primarily because of your expertise in the area of sustainability in dwellings in terms of energy efficiency, in the project Installations 2020. In light of the recent climate policies in the Netherlands, I would like to focus on the relation between the built environment and those climate goals. My approach for the interview would be to talk about one of your past projects, and explore it through my interview framework, which consists of a set of open and closed questions.
2. The research in the form of a teaser or pitch (generic)
    a. Freely translated in English: My research units are CO_2 abatement projects. The starting point is that such projects are complex. From my research

perspective that is to presume that there are non-economic factors at play that determines the likelihood of accomplishing the project and reach its emission ambition. The goal of this research is to gain more insights into those non-economic factors with a set of specific theories. However, i do not want go in on the theoretical framework here for the sake of brevity, but also for the research.

3. My background and credentials (generic)
    a. Freely translated in English: The interviews are part of my MSc "Systems Engineering, Policy Analysis and Management" at the faculty of TPM. The graduation committee consist of Dr. ir. Ivo Bouwmans (head of committee), Dr. ir. Emile Chappin (1st supervisor) en Dr. ir. Els van Daalen (2nd supervisor). The purpose of the research will stay within the scientific community. The intention is to keep it that way as no third parties are involved.
4. Closure and practical affairs (generic, but change according to availability)
    b. Freely translated in English: The interview will last for about 1 hour, and I am available from this moment onward. I am currently working full-time for the thesis, and currently in the start of my interview phase for at least few more weeks. So in principle, I am very flexible at any moment of the day. I hope to hear from you soon. For questions I am available on phone as well from Monday to Friday: 0614695594

The interviewees

The 21 interviews that were carried out may be grouped as follows. In total there are 22 interviewees, this is explained by that one interview was carried out with two interviewees.

- 4 directors
- 4 senior consultants / advisor
- 3 program manager
- 6 consultants / advisor
- 1 professor
- 4 managers

Out of the 21 interviews, 6 are from a Stakeholders perspective, 8 from a Knowledge perspective, and 7 from a Government perspective.

Appendix F – Reconstructing the MACC from report

The reconstruction of MACC for chapter 4 has been done by looking at the respective Sector / Domain of the technical report by Naucler & Enkvist (2009). The method is a simple one, the same type of MACC with the same time horizon has been looked upon and the value in the graph has been estimated. The numbers may therefore vary slightly if compared with the underlying dataset. The technical report did not include the underlying data for every graph, hence this method was used. The method has been systemically used for reconstructing the MACC in this report. However, this should not be done outside this report.

Table 28 – Simplified reconstruction of the MACC

Sector / Domain	**Case study name**	**MACC abatement name**	**€ per ton CO_2**
Heavy Industry	CCU	Iron and steel CCS new build (CCU)	€50
Building	Housing	Retrofit Water Heating residential electric (Housing)	-€15
Energy Production	Wind at Sea	High penetration wind	€23
Forestry	Afforestation	Pastureland afforestation	€10
Agriculture	Green Gas	2nd generation biofuels (Green gas)	€5
Waste	AVI's	Biomass CCS (AVI's)	€45

Appendix G – Combined interviewees descriptions in English

Interviews may be processed in different ways (Adams, 2010). For the analysis of the interviews here, transcripts are not used. The interviews are summarized using on-site notes, and later supplemented manually with audio recordings when the on-site notes were deemed to be unclear. The method for processing and reporting the interviews is as follows: First, the on-site notes were digitalized. As all interviewees were Dutch, these reports are done in Dutch. For each of the 13 factors, the scores and the corresponding comments were digitalized. Then, in the second step, the audio recordings were used. For all interviews, audio recordings were made. This was asked upfront at the start of the interviews. Whenever the scores or the comments are deemed unclear, the audio recordings served as a supplement. If the audio recordings were inconclusive, the score would remain blanc and a x-cross is used to indicate this in the assessment framework. In step 3, the descriptions were translated and combined into one table. In step 4, the keyword analysis is used. Here the corresponding comments of the scores given would be simplified to keywords. The keywords table is used in the main text.

In this appendix, the table of step 3 is shown. The tables of step 1 and 2 are not shown for two reasons. Due to 1. practicalities; such as being in Dutch, and 2. due being too specific details and not relevant to the research lens of this thesis.

The CCU case

K1	K2	G	Why that score?
2	2	2	Not just the infrastructure, aka the pipelines, but also the storage facilities (small) at the horticulture, and the CO_2 "tap" at the horticulture. The process to start it all, also costs 0.5 million.
2	2	2	Because the opex can be way more than €30 per ton, up to (from €12 to) €150 per ton Co2, and thus the investment costs can never be earned back
1	2	2	There is a smaller CO_2 pipeline already. These are established under "reasonable" market conditions. So financing is relatively covered (K1), but the scaling to a more regional/national network is a problem, which is what is going on now (K2,G). The parties want it, but they are all looking at the government. The estimated costs from the gov may use up one third of the annual budget, while they dont have the rationale to do so, because they might not capture one third of the 2030 target (K2).
1	0	2	Only the industrial cluster (K2), the bloc initiative has been paid by only 20+ parties. However, some reckon that parties on the EU-level are involved too, for example the tender organisation. There is actually a whole EU-market of "small" and "big" ccu tenders (G). Looking at it from a demand and supply perspective (K1), the CO_2 users, the horticulture businesses are with thousands in the NL and in this one particular ccu project, there are only two CO_2 producers: an oil company and a bioethanol company.
1	1	2	The CO_2 users are fine, there are enough buyers, we are all dependent on the CO_2 producers, this is dependent on the top 20 CO_2 emitting companies (because you want to have a stable flow). The government, but also the municipality is very important too, as well as the horticulture associations (K1). Basically the whole CO_2 supply chain from sources, infrastructure, to the users, there is a whole business community around it. (K2). (G) we are also dependent on the European tender market
1	x	2	(K1) local residents could be problematic, drilling platforms on the north sea usually fine (G) MinEZ per sector, VNCI (chemicals), and high temperature, nature and milieu, provinces, lots of types.
1	1	1	Seems to be medium clear enough for everybody; the main arguments are the "Klimaat Tafels" (G, P) , these are metaphorical tables with representatives from all across the sector, driven by ministerial departments. Ministerial Climate Accord (P). Climate Law and route map are in the making (G). There isnt a masterplan (K1), yet. Three options generally to consider: BAU (implying slowly improving), invest in green technologies, or put it in the grid. Now its clear, until we talk about 10 years from now.

			Is CO_2 a public resource? Like electricity or gas? That is the big debate. Expertise needed from the regulation experts from electricity and gas in this public/private debate. Not everyone knows their role yet,.
2	2	1	(K2) Large clusters, existing CO_2 pipeline from A'dam to R'dam. CO_2 demand is already almost two times as high as we can provide.Can be higher if there is (geo)heating, because then CO_2 is lacking compared to older heating techniques. (K1) not limited by pipelines underground, but at the tap. The installation at the horticulture, but also at the large CO_2 chimneys. The latter, is the hardest part. Requires large base of support (G), because pipelines through nature is not the same as through an industrial port. Under the city could be different too.
2	1	x	(K1) for new pipelines under the ground (K2) only disturbs the big users, the clusters. (G) only check the tender requirements. The questions G handles are the questions are whether the project is new enough, whether the project can add to future projects, and how much it might contribute to the climate targets. For the physical context of projects, G probably relies on experts.
1	1	1	TRL 3 to 6. New research in how to more efficiently store CO_2 in rocks for example. The "compensation stone". Need more demonstration projects (TRL 7-8) of new prototypes, it's not about demonstration projects of changes to production lines, fabrication process or other existing activities.
0	1	1	(K2) need for CO_2 gas, consortium is aware. (K1) The port of Rotterdam is busy with it, LTO as well. Collaborated with past cabinet agreement, lots of actors are happy that it is mentioned too. (G) cabinet agreement makes it easier, but does not put it more in the scope.
1	1	2	(G) Generally governments and the market parties do not grab these opportunities by themselves. Opportunities are there, such as the Zeeuwse Yara, but only redeemed so slowly. (p1) governments . for the marketparties, yes.(1) Some parties do pursue opportunities more (in general), but not all parties.
0	2	2	(K1) once its there, little changes for the co2 consumer. (K2) Not in the product per se, but the integration with the chain, the chain wants to learn about each other. But that probably requires large changes. (G) largely the same for the CO_2 horticulture, but feels that there is large behavioral changes for non-co2 users given the new CO_2 market and its facilities and plants. However, interviewees are unsure what exactly these behavioral changes are. .

The Housing case

S	K	G	Why that score?
2	1	2	The investment costs may vary from few thousands to 80k per housing. It all depends on the house, some require only a new heating installation (K), while some need a whole new package of "energy module" (10-20k)(S) to complete renovation (80k)(G), with unclear cost structure, for example because there are overdue maintenance.
1	1	2	Longer payback times aren't accepted (S)(K). Depending on electricity price it varies from 5 to 10 years (K). However for some projects, the costs can not be paid back within a reasonable period (G)
2	1	0	Large differences, but they are actually talking about different things. (G) Housing corporations have more leverage in financing; largely due to stable cash flows, and large security.of collateral, but also due to their financial structure through their corporation-network. (K) comments that they basically have larger reserves and bigger loans than private households, but still think it's not easy. (S) Even worse for vve's (homeowners association), they do not have any collateral at all.
2	2	2	Largely fragmented installation sector (S). Mostly small companies, some parties are big (BAM / Volker Vessel), but they also work with smaller contractors. More than 300 housing associations, managing around 2 million of the building stock. Then we have the rest: the private owners, about

			2/3 of the building stock (G). Don't forget the many advisors, builders and in the installation sector. (K)
2	2	2	Not much dependent on the supply chain partners, but very dependent on the actual construction workers and contractors. The construction cant handle that much renovation, the target increased from few to 50 housing per day, now its 100 to 1000 houses per day to be able to reach the target (S). Crucial team of 10 multidisciplinary professionals are needed per housing corporation. So that's at least 3000 professionals for the 2 million dwellings (K). (G) Very much pioneering work, few frontrunners. Seems to be low, but dependency high due to different parties in the construction sector, but also the municipalities, tenant, owners, corporations, energy supplier, etc.
2	2	1	(S) building new housing is easier, and have more returns. When demand increases for new housing, parties will far less likely accept projects of making housing more sustainable. (K) mentions a distrust or a misaligned of interests between the tenants and the corporations. For renovations, 70% of the tenants have to agree. Many tenants have affordability (poverty) and comfort on their agenda, not sustainability. (G) There are three most important actors (in essence): the municipality, tenant and the corporation.
0	2	1	Large difference here again, S comments that there are clear roles. Parties know what to do. It's clear that they apply the "wait and see" strategy. Renovations are large decisions and occur only 20-40 years. G notice that the roles of the corporations are clear enough. However, the other parties are not able to tag along as fast. The metaphorical "radars" or "puzzle pieces" need to work along as well, if one stakeholder stops, then everything stops. It doesn't seem that "direction" or "responsibility" is the problem here of the slow turning radar, but the expertise of the installation sector (G). And to make things worse, the corporation sector and the private sector use the same pool of expertise of contractors (tragedy of the commons-problem). And the private sector seems to win, as they have more profitable projects. (K) comment that are unclarity in when to use the "block" renovation approach or the "one at a time"-approach without any relocation. This largely depends on the location, age or structure of the building and the relation with the tenants. The three talk about the sustainability issue in three different levels. The 2 score talks about renovation approach due to the characteristics of the buildings, 1 talks about the slow moving installation sector. 0 talks about the installation sector that they are simply too few of them, mostly because they leave renovation projects because they have more profitable projects.
2	2	2	Everyone seems to agree that the case is embedded in the environment. S comments on the foreign dependencies of some products, and that the tailor approach of most "block" renovation requires us to have a "renovation-factory" to lower the costs through economies of scale. K comments on the dependencies with the characteristics of the building. E.g. heat pumps requires isolation (of pipelines, walls) to function well. In large complex, it depends on a "public space" assigned for the installations. New buildings are not the problem, standardardization laws make them more sustainable already. G mentions lots of "small" problems, such as surrounding trees (due to PV efficiency), but also the "street image", the city doesn't want standardized and same looking houses everywhere. Dependent with monumental buildings, most inner city housing can not be "renovated" in this way. Some "blocks" are suddenly privately owned, a whole cans of worms opens up then. Within one flat, or complex, houses might also differ significantly (multi-level and multi-object). Technical, but also sociotechnical interdependencies.
2	2	0	Suddenly a large difference here: S and K have 2 as score, while G has zero. G commented on the zero score and said that (NOM) renovation can happen quickly. Some pilots shows record times of within 2 weeks (G), and some renovation with a record time of one day (S). If the occupants are compensated, they dont mind at all. Through show and tell, most occupants are happy to show the neighborhood. Relocation is usually the issue, not many renovations can be done without the occupants leaving the house.
1	1	1	The technology level is assessed by everyone as medium. The heat pumps and other technologies used in conjunction with the heat pump are partially developed, and they are available in the market.

			They are much proven-tech. However, only 0.5% have the latest upgrades for their housing and some installations of energy modules still have to go through the pilot phase. The technology still need to mature, and need to develop more, mostly for driving the costs down.
2	0	1	(2) Probably participated in the writing of the government agreement, but too few people in the construction and installation sector are dealing with it. 1. Sustainability is already for years on the agenda, but because of the climate accord that it is really in the scope now. 0. Sector has been involved for years, also on sustainability issues. Already since 2000. But not with the intensity today. It seems that the sector is involved quite much, but that it doesn't really change whether corporations have it high in the agenda or not. The part that seems to be important is that the construction sector does not have it in their scope.
2	1	0	(1) housing corp experience them somewhat more. Exception exists. Some private owners are quite entrepreneurial and do that via neighborhood initiatives which are co-supported by the municipalities and the grid operator and energy provider. (0) corporations do get such opportunities often. Some old law made the corporations financially independent, and since that law, the corporations have more freedom to invest in economic opportunities, sometimes with disastrous consequences though. (2) comments that this is very new. Renovation for most houses only happens 20-40 years. Setting up such an initiative seems to be always tailored work, as there new local partners everytime the project has to learn to work with. Such initiatives run on being like a learning school for the construction sector.
2	2	2	Many changes for the user and end-users. Houses may appear more big than the direct neighbors and thus may be more appealing for the occupants eventually. Some installations are loud. Air quality may be different too. The installation are "slow systems". Setting temperature may take longer than the older systems. The installation may also change the users behavior in airing houses, making it paradoxically use more energy. Research shows that the relative slow system may cause a rebound effect, and as a result may actually use more energy at the end of the year. There is a need for "smart control". There are experiments of employing gamification to adjust people's behavior towards the slow system, but the experiments shows varying results.

The Wind case

S	K	G	Why that score?
2	2	2	(2) Around €2 million per MegaWatt. So for the current routemap plans. 3.5 GW (2023) its 7 billion euro, for the upcoming routemap plans to 2030, its 7 GW, so thats 14 billion. The 11.5 GW is the one that is mentioned in the cabinet agreement in relation to the 4Mton of CO_2 reduction. Few billions in the electricity transport network.
1	1	x	(1) very hard to say, due to unknown exact business case. Depends on future energy price, depends on the merit-order of electricity and the strike or spot price on the energy market. However, risk based assessment of 10 years usually. Technically, they may last longer.
0	1	0	(0) for the power grid and network on sea there is budget, as long as the tariffs are being paid over time. Financing for platforms should also be doable, because one windpark tender has shown that market parties do not need subsidies anymore. (1) may still be hard due to specific conditions.
x	1	2	(1) workforce 20k in the NL, could grow to 150k like in Germany with expected GW in the routemap (2) Affect the whole coast, the international communities on sea, and interactions with authorities and grid organizations that warrants the safety and balance of the network. Now we have around 100-120 tWh, if we reached the target of 11.5 GW, in peak situation, we may imbalance the whole european network.
1	2	1	(1) for the ongoing projects, there are relatively few parties. Sometimes the winning bid is just one company. Installation sector is quite small, but international. The parties are organized, to compare,

			the windparks on land are much more fragmented, at sea you have dedicated groups, institutes and organizations. (2) many stakeholders for (new) locations for tenders, fishing, nature, shipping, sometimes involving the Council of State.
1	1	1	(1) Procedures bring many types of people together. Opposition might be that the electricity demand is not guarantee, and thus may put investments and shareholders at risks.
0	1	1	(0) The parties responsible for the grid on the sea have enough clarity. (1) For other stakeholders, the procedures are sufficiently clear, people know where to turn to. New “omgevingswet” helps it even further, even though it takes some time. Roles of Ministry I&W, EZk and BZK, seems to be clear enough.
2	2	2	(2) The North Sea is quite a busy place to build with. The location also need to be suitable for regularly maintenance. Dependent on weather, the sea is a harsh place. Need to avoid all navigation routes, and existing pipelines.
2	0	2	(0) after permits, there will be no considerable impacts. Sound, seabed and rock/material pollution will be at a minimum, through agreements. For example (some part of the) construction is not allowed in breeding season of a certain location. Could be built in a year. (2) Platform need to be built on land first, then transported (from across the world, depending who won the bid), usually takes 1-2 years. Most disturbance would be on the net due to the large (sudden) output of wind energy on the grid. The demand for electricity may just be too low. Especially if the “electrification” does not take place.
0	0	1	(0) platform and sea cables are proven tech for decades. Wind Turbines become bigger, faster and more efficient. But there is only scaling issue here. Acceleration phase of technology, not yet mass adoption. (1) “Chem on Sea” is still undeveloped, and technology there is very fundamental.
1	0	0	(0) very informed, no surprise, through past energy akkoords. (1) grid operators have do no have an active role for cabinet agreement.
0	0	0	(0) quite some experience with past wind parks. Grid operators follow policy cycles due to their nature with the state. The wind turbine supply chain is quite dynamic and moves very fast. It is a world market.
0	1	2	(0) not relevant for majority of the nation, just for a few its horizon pollution. (1) Coast location may actually change through increased tourism. The classic NIMBY problem is less compared to onshore wind. (2) however given the ambitions, we need the whole society to adapt to the “electrification movement”. Future supply of wind energy are not aligned with the future transport capacity, and future demand. Peaks in the grid will be more frequent and more steep too.

The Afforestation case

S	K	G	Why that score?
2	2	2	Afforestation is expensive, the land or ground price make up the largest costs, about 10k-200k per ha. An average of 30k per ha is assumed. In preliminary plans, the total costs will be shared by the government for 60%.
2	2	2	Forest are characterized by long payback times. Often payback time are just not mentioned. Owners just look at whether the maintenance can be paid through the periodic income of the forest.
2	1	2	Financing a forest is difficult. Current forest ownership is a product of legacy. You became landowner, and you had a forest on it or not. Its often from heritage. Due to uncertain business models, afforestation isnt easy. If there is political will then it might happen.
1	1	1	Many actors are involved, it is about an area of 100 ha, this is bigger than the Veluwe. It is not about millions actors though.

1	1	1	In the Actionplan, about 20+ actors are seen as being dependent on. The provinces, who are missing in the list, are seen as important.
0	2	2	One counteroffensive of the Actionplan can be identified. This was most apparent after the media article in Trouw in the same month of the Actionplan. The provinces were shocked, but mostly because they were not involved in the process. Other actors can be found in the old, but still existing discussion of food versus nature. The difference now seems to be the new Climate vs Circular Economy discussion. Its a discussion about wood and all its wood products and chain partners, should or should not be part of the climate “solution”..
1	1	1	A certain vision is still mission. People are working on it, an upcoming plan seems to be on the horizon with another name. Some roles seems to be missing though, the Actionplan has opened up many dialogues. Many are picking up their roles in a positive way in the process of the current Actionplan. A gap has been bridged, but others remain.
2	1	1	There is an impression that forest projects are strongly dependent on their physical environment. The land prices in are much dependent on what’s in the direct vicinity. It is about regional development processes and their plans. These influences the afforestation projects strongly, but in principle many areas can be allocated for afforestation. Recently people are thinking of forestry along highways, many options are to be explored.
0	0	2	There is a large difference. In the implementation, biodiversity may be disturbed. Think of the Dutch “weidevogels” or the “wielewaal”. This is because more afforestation may mean that there is more competition from other bird species, or that there are “wrong” types of forests. For example, forest that are too dense. Forest or terrain owners may do afforestation, and this imply a certain business model, this may disturb the surrounding business. However, the new Omgevingswet, an environmental lew, provides enough clarity and seems to perform good enough for minimal disturbance.
1	0	0	Afforestation is no technological science, however, it is about systems innovation. “Bospilot” or forest experimentation exist. A toolkit is being made, this toolkit is a sort of catalogues of actions that governments and private organizations may take (a variety of them). In terms of research, some exists to create plastic from wood, and new ways to do afforestation (QD method) for a better wood yield is being researched.
1	1	1	The Actionplan has gotten the attention of the political realm, but it seems that some respondents are surprise that they are not explicitly mentioned in the past cabinets agreement. In 2016, several ministers (Rutte and Dijksma) were presenting the Actionplan. It could be very well possible that some forest managers are not interested. Other measures beside afforestation exists in the Actionplan, but they are not that well known.
2	2	2	The forest sector is a very slow moving sector. The assets, the tree, require a long startup time. But some people notice that there hasnt been such a spectacle since at least 20 years back. Back then, there was extra attention for extra forrest. The discussion is also back, more nature or production forest? There is a dilemma between creating high quality and long lasting furniture (as a function for CO_2 storage) or just afforestation and leave them there. In the lon term, this may mean less CO_2 storage. After a while trees do not capture as much CO_2 as one think.
0	0	1	There are few talks about behavioral change. Forest are appreciated highly in general. Extra forest in environmental doesnt ask that much of a behavioral change. Forest may increase comfortable living through warmth retention. Sometimes, especially nearby cities,

			citizens may think that they have right to trees and forest. In some areas (Twente) the citizens are quite familiar with cutting trees. Some awareness for climate and forest, wood and climate is missing. The citizens know that this is promoting forest growth. One thing that might never change is the fireplace at home or wood for campfires. They are actually the worst in terms of CO2, the require long production time, and the CO_2 doesnt get store long.

The Green Gas case

S	K1	K2	G1	G2	Why that score?
2	2	2	2	2	2 expensive capex, but also opex. Around 200k to 800k, and opex is mainly determined by biomass purchase, €25-70 per ton. Evaluation "fermentation-chain", biomass is around 1/3 to 1/2 of the costs" (2011).
1	2	1	1	1	(1) 10-12 years. Mostly due to maintenance sensitive installations, but also because of the subsidy periods. (2) The gas fermentation is still too expensive, and has no payback time.
2	2	1	2	1	(1) Most of the installations are not viable, without subsidies. The business case is not that much cheaper with better and green gas. (2) Subsidies are irregular and variations in business cases are limited, and most of them are not suited for smaller companies
1	1	1	1	1	(1) 118 tenders has been awarded in 2017 in mostly Friesland. There are not many places where this is relevant. Definitely not in the millions. Green upkeepers, LTO, farmers, the WKK users.
1	2	1	2	2	(1) cattle farmers are important, so is the government. (2) the banks, milk-industry, and manure industry, forestry and other biomass sellers. There are many sources for biomass, but it's quite unclear who they are and where they are from exactly.
2	0	1	1	1	(K10) the anti-gas movement and the CE-movement (K21) food or fuel discussion. Residence in direct vicinity; (G11) connection and transport obligation, compression, new role for network operator to create more balance on the network for gas injection for the new local supplier (G21) uncertified biomass suppliers (S2) municipalities, province or state for certain waste/biomass supplier, permits needed.
1	1	2	0	1	(0) Just need an industrial bio-installation. Tennet and Gasunie may warrant quality, certification and transport of the gas. (G21) CO_2 story that we should use "fossil fuel" is clear enough, but there unclarities with how to approach it because the horticulture entrepreneurs (small and big) are quite different. (S11) demonstration projects with a general and specific subsidy, however unclear about future path. (K11) horticulture wants green gas, but the government has no concrete plans for it, it seems that the gov focus their subsidies on other sustainable energy. (K22) unclear position in the future "energy-mix", unclear role of the "full" bio-based economy in relation to other sustainable renewables.
1	2	1	1	0	(2) Dependent on the gas network, dependent on the (availability of) waste flows of manure, garden and other green waste, and their physical location. (K11) dependent on gasnetwork, permit for the bio-installation, but there should be too many direct neighbor. (G11) dependent on seasonal variations (especially in the summer nights), gas network may be unavailable (too full). (G20) in principle everywhere, but generally in east-NL. May come from sewage treatment system (in Dutch: RWZI), may be determined distance to available biomass hotspot. (S1) dependent on the availability on two types of biomass; dry or wet.
1	2	0	x	1	(0) own terrain, shouldn't bother anybody. (2) In practice your business will be affected, you basically need to maintain and upkeep a quite large installation, you also need to have a gas-storage place. (S1) new roads, if there is no pipeline, heavy transport. (G21) you need back nevertheless for your greenhouse, in the case there isn't enough biomass. (G11) yearly gas

					quality checkups, local supplier need to accommodate the quality assurance process.
2	0	0	1	1	(K10) upgrade to green gas is commercial, has been like this for years. (K20) green gas of manure and waste is proven tech, however there is a need for more efficiency technologies. However, syngas is not proventech. Fermentation is proven tech, but gas fermentation is not. Syngas is lab-ready though. (G11) green gas is already in gas network, however very low and some technologies such as syngas and gas from algae are still highly uncertain. (G21) pilots with gas fermentation of "sugar cane" (Glazenstad), but still somewhat uncertain (2) from upgrading biogas to groengas there is still a long way to go. Especially syngas and "supercritical gas fermentation" is far from proven tech.
1	0	1	0	0	(S1) not specific in cabinets agreement, room for geothermal energy. Knowledge platform KAEk not out of the scope. (G10) due to grassland and land fallow regulation, land can be used differently to promote its productivity. (G20) due to their multi-year strategic plan of the horticulture, also due to a "clean and efficient" covenant in the whole agriculture sector, within most people's scope (K21) doesnt know whether all farmers are looking forward to this equally (K10) sector has had CO_2 targets before. The frontrunners are there for sure. LTO is usually the ones who gives input for the cabinet directly.
1	0	x	1	0	(S1) horticulture can act fast on such opportunities, see Dutch WKK example in 2004/2005. (G11) mostly triggered by manure-overload. May disturb surrounding neighbors, sometimes large court cases to halt the development of a nearby bio-installation. (G21) due to recent developments in "warmth and cold storage" and "district heating", farmers and municipalities are quite entrepreneurial. Fits in their natural investment moments. (K2x) n/a (K10) A very entrepreneurial sector, especially the greenhouses, often just 2 partners, can be quite opportunistic and can act relatively fast. Some geothermal project are initiated by the greenhouses themselves even.
2	1	2	2	2	(S2) additional attention needed for the bio-installation. (G22) societal change, farmers will get closer to civilians, horizon, smell, but also increased transport movements. Due to periodic performance tests of bio-installation, the farmers have to adjust their working schedules. (G12) farmer has to spend a few hours per day with the installation. In principle an additional company. Sometimes this is not part of the farmer's passion. Sometimes farmers may not even have the capacity, because they are too small. (K22) farmers need to adjust, experts will drop by, maintenance need to happen. O, also storage place for the biomass is another point of attention. (K11) at the greenhouses there are hardly any changes, the outside farmers might show behavioral changes, for example, you need take a course for the operation of the installation. They are small things though, but sometimes neighbors may complain.

The Waste case

S	S	G	K	**Explanation scores**
2	2	2	2	CAPEX are in the million euros, resulting in usually tens of euros per ton CO2 to pay it off. However, the OPEX are even higher: from 30 to 300 euros per ton CO2.
2	2	1	1	Payback period is mostly determined by the high operational costs of the carbon capture installations. Paying back the investment can be done between usually around 10 years (as explained by the “1” scores), but the high operation cost, makes the payback time very long (as explained by the “2” scores).
2	1	0	1	Multiple subsidies seem to be required, and that is experienced as a large hurdle (as explained by the “2” scores). However, AVI's are "traditional" businesses with predictable business cases (as explained by the “1” scores), and additionally some AVI have a shared public cause with a municipality (as explained by the “0” scores).
0	1	0	1	There are about 13 avi's in the Netherlands, and they are owned by about 9 companies, because

				some companies own two AVI's. And for a carbon capture installation, the responsible installation sector is small, around the 100-200 companies (as explained by the “0” scores). When envisioning the future CCU market, interviewees still talk about a relative small actor pool, as they estimate that it range from hundreds to thousands of CO2 consumers (as explained by the “1” scores).
2	2	1	1	AVI’s are only dependent on their municipalities (around 50% have a co-ownership structure) and dependent on the environmental agency. However, the interviewees see this as having low actors to be dependent on. (as explained by the “1” scores). Interviewees who seems to experience large actor dependencies mentions the many actor dependencies with the installation sector, such as the civil contractors, but also the equipment and engineering companies that sometimes come from abroad (as explained by the “2” scores).
1	2	0	0	The waste sector has their own social professional network. Some interviewees do not experience many different types of actors (as explained by the “0” scores). The (plastic) material industry has always been a different type of actor for the waste industry. So is the material industry, as they wants more design and more complicated material. This is experienced as having a stark contrast with the interests of the waste industry, as they are left with more and more expensive sorting and separation techniques (as explained by the “2” scores). The waste sector still need a public consultation process (albeit a local one as opposed to a national one). But this process is experiences as having little problems, as the waste sector has a good public image generally (as explained by the “1” scores).
0	0	1	2	The AVI’s currently have good relationships with the citizens, but also with the municipalities. Past ambitions of the sector to be more environmental friendly in terms of soil, air and sound pollutions has generally worked out fine. New CO_2 ambitions goals (and existing procedures) are perceived as similar and are as far as the interviewees can see, sufficiently clear now (as explained by the “2” score). However, some notice an absent of a more central (high-level) board (as explained by the “0” scores and feels that a vision or roadmap is lacking from the industry. Some assume that there is already a high-level board, but only a ministerial high-level board (as explained by the “1” scores). The first member of such board could be the “large” and public AVI’s with large CO_2 market as frontrunners.
H1	J 2	O 1	LR 0	One answers seems to be about how the CO_2 installation will affect the environment. But not the other way around. How does the environment affect whether or not there will be a CO_2 installation? Another is saying that AVI's can be placed everywhere in principle. AVI's only need some road infrastructures. Ín the past, AVI's were built where there is a high supply of waste. For CO_2, the AVI who is the closest to horticulture hotspots will be more likely to be built. A CO_2 pipeline infrastructure will be more cost-efficient for a carbon capture installation (afvang installatie). One said something similar; AVI's close to an OCAP like infrastructure will contribute to a better business case for a carbon capture installation. However, transport costs for trucks are low, but storage is expensive, and pipelines inherently has some storage capacity. One comments that generally AVI have been and will be very flexible, it does not depend on much physically. It just needs a certain supply. Road infrastructure is not even considered to be a determining factor.
1	2	1	0	Some do not see any disturbing in the daily operations, especially if they install at "regularly / planned" maintenance. Then it's just part of their routine, and it wont disturb. However, others do see some disturbance. The chimneys might need to be diverted, this might take some time to relay the fumes from the chimneys. Installations can be built without much disturbance. O notes that there might have to be extra storage capacity to act like buffer for the trucks to load and unload. The carbon capture installation will need that in order to function properly. Storage tanks can take up considered amount of space that will need another building permit. J find that disturbances can be quite high: The chimneys' height will probably be affected due to environmental regulation. The current situation is that the fumes are hot and according to simulation models, they will dissipate quite evenly due to the height hot fumes will reach. With a carbon capture installation, the fumes will

				be much more cooler. The effect will be that the fumes will cover a far less big area, making the concentration an issue for environmental regulation. The "waste water" will also be different now, and has to be examined and comply to water disposal rules again.
2	2	0	x	Here there are two opinions: That it has never been done, it has been done in Finland, but not at the AVI's in the Netherlands. Some comment that reusing CO_2 is at the bottom of the innovation curve mostly because of the new safety and quality requirements. Especially, the wastewater (and the fumes) that comes out of it is new in this context. One comments that "open-source" technology or open innovation exists for storage, and that they choose that particularly one to build. It's been commented that this is quite unique! And that this particularly setup has never been done before in this context. Other areas where there is technology uncertainty is at the application side of CO_2. Such as CO_2 as built material. That is still in R&D. Another comments that there the technology there is mostly TRL 6 or 7.This means that it is about upscaling and "supply chain innovation". It is about the maturity of the CO_2 market; are there enough CO_2 buyers?
1	1	0	1	The waste sector is usually aware of the broader policy context through the branche association. The branch association might have provided the CO_2 emission targets to the recent governmental coalition agreement (as explained by the “0” score). Some AVI’s might be surprised by the recent CO_2 ambities, but they should be aware of huge CO_2 output, as CO_2 reporting and monitoring has been going on for decades. The diffusion of knowledge seems to be good, but not comprehensive throughout the network (as explained by the “1” scores)
0	0	0	2	The waste sector is quite responsive by market opportunities. “AVI's live from policy changes” (as explained by the “0” scores). Some AVI's are slow, cumbersome and and have only acted upon a handful of opportunities (as explained by the “0” scores). For others, the AVI's seems to be quite entrepreneurial and relevant opportunities were taken especially in the last 10 years, such as the Green Deal for “bottom ash”, district heating (2010-2015), steam for chemical plants, (2003-2013).
1	0	1	0	Behavioral changes are not much of a topic (as explained by the “0” scores). The only change that seems relevant is the change of working with a new product for the food industry in the context of food safety. Behavioral changes include the working procedure or practice of the direct involved, such as for the truck contractors in the supply chain (as explained by the “1” scores). Behavioral change at the level the end-users (horticulture) or even citizens, are not present.