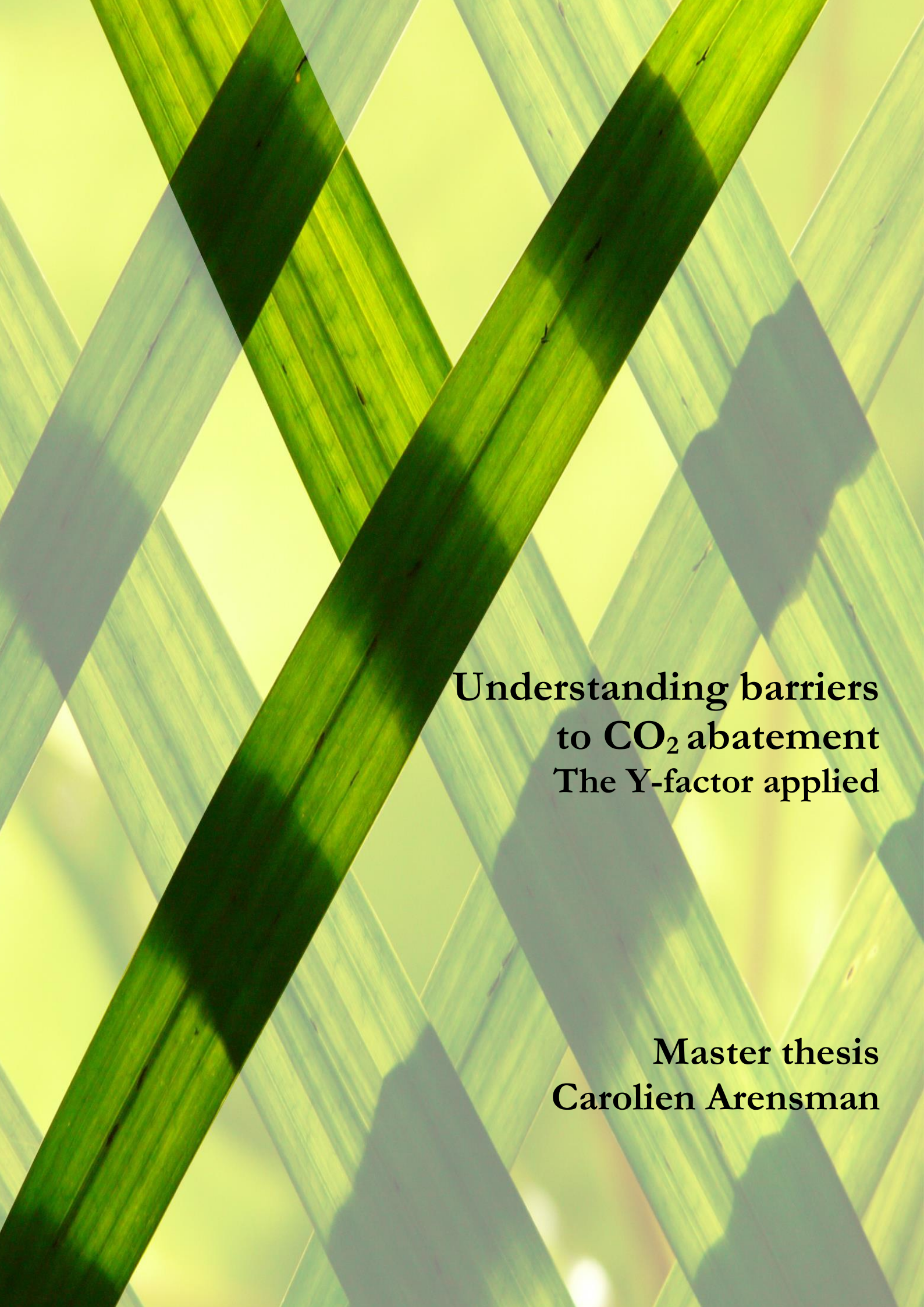

Understanding barriers to CO_2 abatement
The Y-factor applied

Master thesis

Carolien Arensman

Understanding barriers to CO_2 abatement

The Y-factor applied

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Carmenta Evita Christien Arensman

Student number: 4227689

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Graduation committee

Chairperson:	Dr. ir. I. Bouwmans,	Energy and Industry
First Supervisor:	Dr. ir. E.J.L. Chappin,	Energy and Industry
Second Supervisor:	Dr. Mr. N. Mouter,	Transport and Logistics

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When starting a thesis, the first task is to select the topic of your preference. This was quite a quest for me, but after some time I had defined the right criteria and was able to choose this topic with confidence. I wanted to learn about the real struggles of the energy transition, not get 'isolated' during the research process and be guided by a supportive team of supervisors. Looking back, I must say that all my criteria have been met!

I want to express my gratitude to a number of people First, I want to thank the fifteen interviewees for their cooperation and the interesting insights they provided that formed the basis of this research. I enjoyed travelling to such different locations all across the Randstad during the cold but sunny weeks in February and March.

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Enjoy the read!
Carolien Arensman

Delft, May 2018

Executive summary

The signing of the Paris Agreement by almost all countries of the world in 2015, expresses that the urgency to implement CO_2 abatement options is widely acknowledged. However, the materialisation of many abatement options is hampering. In 2009, McKinsey and Company published an overview of the cost and potential of a wide range of CO_2 abatement options with their publication of the Marginal Abatement Cost Curve (MACC) (Nauclér & Enkvist, 2009). The curve implies to policy-makers that materialisation costs are the main barrier to CO_2 abatement. However, this neglects the fact that the abatement options must be implemented in existing technical structures, the current institutional setting and in the living environment of citizens.

Chappin constructed the Y-factor to provide more insight into the barriers that may impede materialisation of CO_2 abatement options (Chappin, 2016). He divided thirteen barriers into four categories, namely: costs and financing, multi-actor complexity, physical interdependencies and behaviour. The evaluation of the fifty cheapest options from McKinsey's MACC using these barriers showed a reordering of their likeliness of materialisation. He could therefore conclude that it is relevant to look beyond realisation costs. To further increase the knowledge on materialisation barriers, the central question of this thesis is formulated as follows:

How can the understanding of the barriers to CO_2 abatement in the Netherlands be improved?
This research consists of a literature study and expert interviews on four abatement options where the Y-factor was applied. The analysis of the interviews led to various insights on barriers and resulted in recommendations on using the Y-factor and the research into barriers to CO_2 abatement in general.

The main conclusions from the literature study are that the Y-factor complements the MACC by its transparent scoring method, coverage of barriers other than costs and acknowledgement of complexity due to the inclusion of a range of barriers (see left columns figure 0.1). The four Y-factor categories are reflected in other literature relevant to materialisation barriers such as the IPCC-report (International Panel of Climate Change) and theoretical research frameworks. However, the high conceptual level of the frameworks lacked detail to support the set of thirteen barriers. This results in the conclusion that the Y-factor is more concrete and operational than the research frameworks it was compared to and can be classified as a research method.

A multi-criteria selection process was used to select four abatement options from the fifty evaluated options by Chappin (2016). The criteria excluded abatement options that are not applicable in the Netherlands; are already actively implemented; showed low Y-factor scores and comprised of packages of measures. This led to the selection of the following CO_2 abatement options:
- **Insulation**: Focus on private home owners and houses with cavity wall and floor insulation possibilities
- **Carbon Capture Storage**: Focuss on industrial parties/networks and full-chain projects of CO_2 capturing, transport and (offshore) storage
- **Biofuels**: Focus on private car owners and biofuels with a high percentage of bio-based raw material
- **Geothermal Energy**: Focus on horticulturists as project initiators that change to geothermal energy for heating their greenhouses

The selected abatement options are part of different sectors: the built environment, industry, transport and energy. All Y-factor barriers are indicated by Chappin and could be researched. Hence, this selection was concluded to be representative.

Three or four expert interviews per abatement option have been conducted. The goal of these interviews was to learn about the materialisation barriers specific to the abatement technologies by discussing the Y-factor barriers. The interview results are the barrier scores for each abatement option combined with an elucidating narrative that supports these scores. Figure 0.1 shows the barrier scores of the four abatement options.

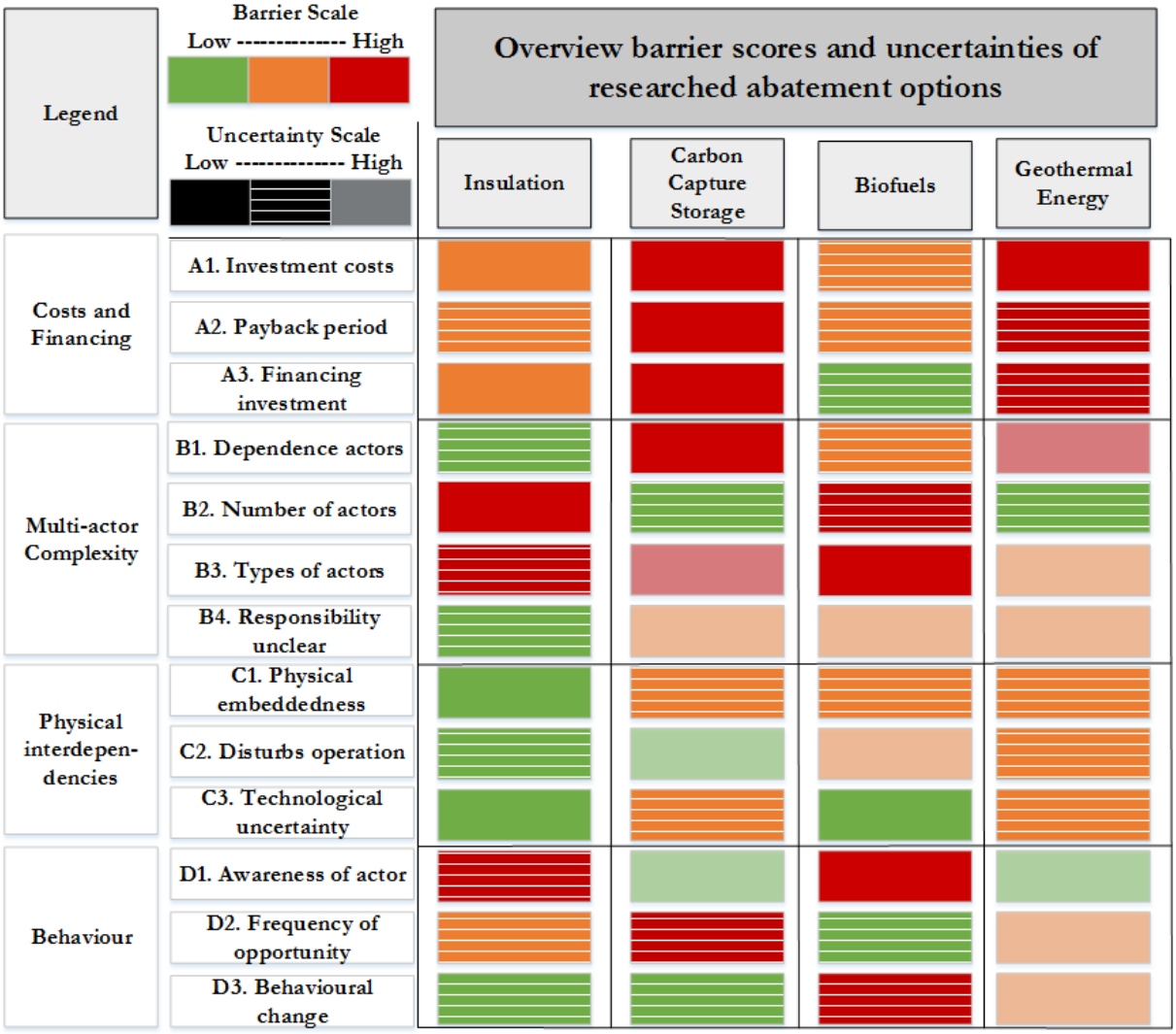

Figure 0.1 Barrier scores of four abatement options

The relevance of all thirteen Y-factor barriers was supported by the narratives on the abatement options that were summarised from the expert interviews. When comparing the scores, it should be kept in mind that these are reasoned from the project initiator (e.g. a household that installs insulation or an industrial network that decides to capture and store CO_2). Perceived barriers are as important as 'objective' barriers, as these do impede materialisation. Barriers can be scored as 'high' due to the perception of the initiator on the presence of this barrier. The narratives supporting the scores are therewith essential to the comparison of abatement options. Two generic challenges for abatement options were concluded from the interview analysis. The main challenge for abatement initiated by households is to adequately inform a large heterogeneous group. The main task to stimulate materialisation of capital-intensive abatement options is reducing the uncertainty on the investment from for instance regulations or geology.

Several links between barriers were found, 'cause-effect' links and ' common couples' of high scores that displayed characteristics of the abatement options. The barrier scores proved to stable over the past ten years in the researched options. From the analysis of interventions to reduce barriers it resulted that interventions of various nature (regulatory, financial and informative) can be relevant to reduce barriers in different categories.

The supporting stories as well as their scoring showed some variance (uncertainty in figure 0.1). These variances arose predominantly from a different frame of reference between the interviewees (e.g. different levels of scale: project or national level). Other less-frequent sources were: an ill-fit with the Y-factor categorisation of case-specifics and a difference in understanding of barrier definitions (mostly D2, frequency of opportunity). For more than one third of the observed variances, no source could be assigned.

The recommendations of this thesis focus on definitions of the Y-factor; additional scoping to reduce variance and a method on researching abatement options.

To increase the clarity of the Y-factor definitions it is recommended to remove barrier B2 (number of actors) and add 'public acceptance' to barrier B3 (types of actors). The characteristic that is caught in barrier B2, a high number of initiators, also reflects in a high score on B3 (large heterogeneity of actors) and a low level of awareness (D1) of this large group. The concept of public acceptance (a favourable reception of the (local) community), is recommended to include in barrier B3 as half of the interviewees indicated this as a missing barrier. A high score on B3 (types of actors) reflects the presence of opposition from the community. Remaining recommendations focus on smaller changes of several barrier definitions.

This was the first research that applied the Y-factor in interviews with experts on abatement options. The following steps are recommended to gather specific information and increase the understanding of the barriers to CO_2 abatement. Before starting the study of an abatement option, it is essential to scope with respect to: geography (preferably on a country-level), the initiating actor and the physical boundaries of the 'abatement project'. This results in a specific supporting story for each barrier that is essential to understand the cause of the barriers. One should verify if the Y-factor barriers include all complications of the abatement option to create a complete story. The understanding of the barriers can be increased by investigating links between barriers and analysing if barriers changed over the past years. This offers the possibility to reflect on the robustness of barriers and the effectiveness of past interventions. An overview of current and potential interventions offers options for policy evaluation. A similar approach (without the scoring aspect of the Y-factor) could also be used in researching abatement barriers in general.

Future research on understanding barriers to CO_2 abatement could have different directions. First, research could explore how the Y-factor might be used for policy evaluation purposes by linking current and potential interventions to Y-factor barriers. Second, abatement options within one sector can be compared to see if similar barriers are observed. An intervention strategy on sector level could potentially be developed. Third, a design could be developed to weigh the importance of barriers in abatement options. This would show where most attention is needed to reduce barriers for an abatement option.

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1. Introduction

In this chapter, the motivation for this research is presented. First, the problem is identified and described (1.1 and 1.2). This leads to the knowledge gap and the main research question of this thesis. The outline of the research concludes this chapter and is shown in section 1.3 .

1.1 Problem identification

The signing of the Paris Agreement in 2015 by almost all countries of the world expresses that the urgency to implement CO_2 abatement options is widely acknowledged. Next to this urgency, it shows that the willingness to act is present by the world leaders. However, shifting to a new CO_2-neutral energy system is a large challenge. This section describes several examples of CO_2 abatement options and the challenges of implementing these in the Netherlands.

Different barriers impede the materialisation of CO_2 abatement options

For the Netherlands, one of the largest tasks is fitting the sustainable, CO_2 neutral energy production options (e.g. wind and solar energy) into the Dutch landscape. As the energy density of these technologies is significantly lower than, for example, energy production from coal, larger areas are needed for the production (Vereniging Deltametropool, 2017). Since solar and wind energy are present in every scenario to reach the climate goals of 2050 in the Netherlands, this will have a visible impact on the landscape of especially rural areas (Ros & Koelemeijer, 2011; Vereniging Deltametropool, 2017).

The energy production from several renewable energy technologies is intermittent, due to their production being dependent on the weather. As the sources are larger in number, the physical electricity system must be adapted: Storage solutions and an increased backup capacity are needed to keep the electricity net balanced (Heide et al., 2010). Prediction of the supply and demand will become increasingly difficult. This leads to challenges in the balancing of the network as well as the capacity of the physical infrastructure.

Carbon Capture Storage (CCS) is stated to be essential by the Netherlands Energy Assessment Agency (PBL) to reach the climate goals (Ros & Koelemeijer, 2011). CO_2 is captured at electricity production facilities such as coal fired power plants. The storages are often empty gas fields. CCS has not yet been successfully implemented in the Netherlands. In Barendrecht the public proved to be the deal-breaker for setting up the first storage (Kuijper, 2011). Next to social opposition, the physical storage and infrastructure require both a spatial fit as well as investors (International Energy Agency [IEA], 2016).

In April 2015, minister Kamp presented his 'heat vision' to the parliament (Kamp, 2015). It contains aims on reducing the demand of heat as well as reducing the use of natural gas for heating. Several options exist for changing to other heat sources than natural gas. Examples are heat networks that use residual heat, heat pumps or electric heating (Ministry of Economic Affairs, 2017). This demands adaptions on a district-level as well as on individual houses (insulation). This means investments and planning is required from municipalities and actions are needed from households all over the Netherlands.

Urgency for CO_2 abatement

In the examples in the introduction, it shows that barriers for implementing CO_2 abatement options can have different origins, for instance of technological, economic or social nature. The combination of these barriers can differ for every CO_2 abatement option. These barriers impede or block the materialisation of abatement options. The urgency to accelerate implementation was stressed in the Climate Conference in Bonn of 2017 as well as by the UN in their Emissions Gap Report of 2017 (United Nations Environment Programme [UNEP], 2017). For the Netherlands, the progress report of 2016 of the Energy Agreement shows that two out of five goals for 2020 are not yet in reach (Sociaal-Economische Raad [SER], 2013). These goals are related to increasing energy savings as well as the renewable energy share. Implementation is happening at a slower pace than expected.

Therefore, it is important to increase the understanding of the combinations of barriers to CO_2 abatement. This can aid in developing an adequate plan of action to reduce or manage the existing barriers.

1.2 Problem description

This section introduces the Y-factor as a research method for the identification of barriers to CO_2 abatement. This is followed by an elaboration on the knowledge gap leading to the main research question for this proposal.

1.2.1 Marginal Abatement Cost Curve

In 2009, McKinsey and Company published the Marginal Abatement Cost Curve (MACC) (Nauclér & Enkvist, 2009). This curve shows overview of the potential of a wide range of CO_2 abatement measures ordered by their implementation costs per Mton reduced CO_2 emissions. This analysis received many critical reviews from the scientific community with respect to its non-transparent method and the absence of essential elements such as uncertainty, complexity, interacting measures and path dependency (Kesicki, Ekins, & Smith, 2011; Kesicki & Strachan, 2011). The curve leaves the impression to policy-makers that the financial aspect is the main barrier to the implementation of CO_2 abatement options.

However, the abatement options must be implemented in existing technical structures, the current institutional setting and in the living environment of citizens. Are investment costs the only explanatory factor that impedes CO_2 abatement?

1.2.2 Introducing the Y-factor

In 2016, Chappin constructed a method, the Y-factor, to provide more insight into barriers that may obstruct the materialisation of CO_2 abatement options (Chappin, 2016). In his paper, Chappin evaluated the fifty cheapest abatement options from McKinsey's MACC with respect to their likeliness of implementation. The solely economic view of the MACC was replaced by the Y-factor barriers to rate the options. The Y-factor (Y = Why does implementation hamper?) includes four categories of barriers. These categories are: Costs and financing, multi-actor complexity, physical interdependencies and behaviour. Table 1.1 shows the components for different categories. Chappin's conclusion of his reordering was that it led to a rather different curve and hence barriers beyond implementation costs were relevant to the understanding of materialisation of CO_2 abatement.

Table 1.1 Y-factor method. Reprinted from 'Complementing Weaknesses in Marginal Abatement Cost Curves' by E. J. L. Chappin, 2016. International Association for Energy Economics. 31, p.1.

Table 1. List of factors and score definitions.

Category	Factor	Value 0	Value 1	Value 2
Costs and financing	Investment cost required	Absent	Medium	Large
	Expected pay-back time at €0 euro/ton	< 5 years	5-12 years	> 20 years
	Difficulty in financing investment	None	Medium	Large
Multi-actor complexity	Dependence on other actors	None	Few	Many
	Number of actors	Few	Many	Millions
	Types of actors involved incl. conflicts	Low/none	Medium/medium	Many/large
	Responsibility unclear	No	Slightly	Unclear
Physical interdependences	Physical embeddedness	No	Medium	Strongly
	Disturbs regular operation	No	Slightly	Strongly
	Technology uncertainty	Fully proven	Small	Large
Behavior	Outside of thinking scope of actor	No	Partly related	Outside
	Frequency of opportunity	Often	Medium	Rarely
	Requires change in behaviour	No	Slight	Severe

The Y-factor consists of qualitative barriers that can be scored by selecting one of the three options per category. A barrier with a score in the right column is not twice as difficult to overcome as a barrier in the middle column in table 1.1, it is only more difficult. A score in the right and middle column indicate the relevance of a barrier for that abatement technology. The definitions for the barriers that are used in this thesis can be found in table 1.2 at the end of this chapter and in appendix D.

1.2.3 Knowledge gap and main research question

In the paper of (Chappin, 2016), the Y-factor was present to complement the evaluation of materialisation barriers for abatement options. Fifty abatement options were evaluated by using this method and led to the conclusion that barriers other than investment costs are relevant to the understanding of the materialisation of CO_2 abatement options. The diverse set of barriers that is shown by Chappin may lead to different choices of policy-makers on which abatement option they should support. The Y-factor has not been tested yet but is promising to increase the understanding of materialisation barriers. This leads to the following main research question of this thesis: determine the barrier scores for the fifty abatement options. This led to a reordering of the abatement options and the conclusion that barriers other investment costs are relevant in the materialisation of. The diverse set of barriers that Chappin shows, may lead to different choices of policymakers on which abatement option to support. The Y-factor has not been tested, but is promising to increase the understanding of materialisation barriers. This leads to following main research question:

How can we improve the understanding of the barriers to CO2 abatement in the Netherlands?

In this thesis the Y-factor will be used as a means to increase this understanding. The method shall be tested for the first time by applying it in expert interviews in four case studies. An additional aim for this thesis is improving the method itself based on the findings in the interviews. The following sub research questions will be used to reach these goals and ultimately answer the main research question:

1. *Can the Y-factor barriers be supported by literature relevant to materialisation barriers?*
2. *What is a representative set of case studies for CO2 abatement in the Netherlands?*
3. *What are the Y-factor scores for the cases and what is the underlying rationale?*
4. *How can the Y-factor be improved based on the obtained insights?*

1.2.4 Societal and scientific relevance

An acceleration of the materialisation of CO_2 abatement options is essential to reach the goals of the Paris Climate agreement and limit the negative effects on the quality of life of climate change. However, the materialisation of abatement options is currently impeded by the presence of various barriers of different nature. The understanding of these barriers is vital to take adequate actions to reduce these barriers. The Y-factor aims to identify the variety in barriers for different abatement options. This thesis contributes to the enriching the understanding of these barriers. This aids the development of adequate interventions to reduce materialisation barriers. Ineffective interventions to reduce implementation barriers are costly as well as resulting in to a lower quality of living.

The scientific relevance of this thesis is the enriched understanding of four CO_2 abatement options. Through researching barriers in four different sectors, more general lessons can be concluded on these barriers. The expert interviews provide suggestions for refining definitions of the Y-factor and support the relevance of the barriers that are included in this method.

1.2.5 Fit with Complex Systems Engineering and Management

The central research method in this thesis is the Y-factor. This method comprises of economical, technical and multi-actor elements. The discussion of these elements demands applying of the system's perspective, which is an essential element of the master. The abatement options are technologies that can be related to the energy and industry domain of the master. The deliverables of this research include recommendations on refinement of the Y-factor which relates to designing.

1.3 Research approach

In this section the research approach will be presented. This is followed by the research flow diagram, which shows the research sub questions which lead to answering the main research question.

1.3.1 Literature review

The goal of the literature review is to collect an underpinning for the thirteen barriers of the Y-factor. This review can also shed light on the 'completeness' of the current selection of barriers. This leads to the following sub research question:

1. Can the Y-factor barriers be supported by literature relevant to materialisation barriers?

First, the critiques of the MAC-factor (which the Y-factor aims to complement) are discussed. Second, general barrier literature on different sectors are analysed to underpin the relevance of the Y-factor barriers. The IPCC report of 2014 (Intergovernmental Panel on Climate Change, 2014) is studied as this summarises the views of many researchers from all over the world. Last, theoretical frameworks that evaluate barriers for transitions or the implementation of renewable energy technologies are compared to the Y-factor barriers. A selection of frameworks from transition literature was made from the literature review of Lachman (2013). The framework of Painuly (2001) is analysed to compare barriers of the penetration of renewable energy technologies to the Y-factor barriers. The literature review is summarised in figure 1.1.

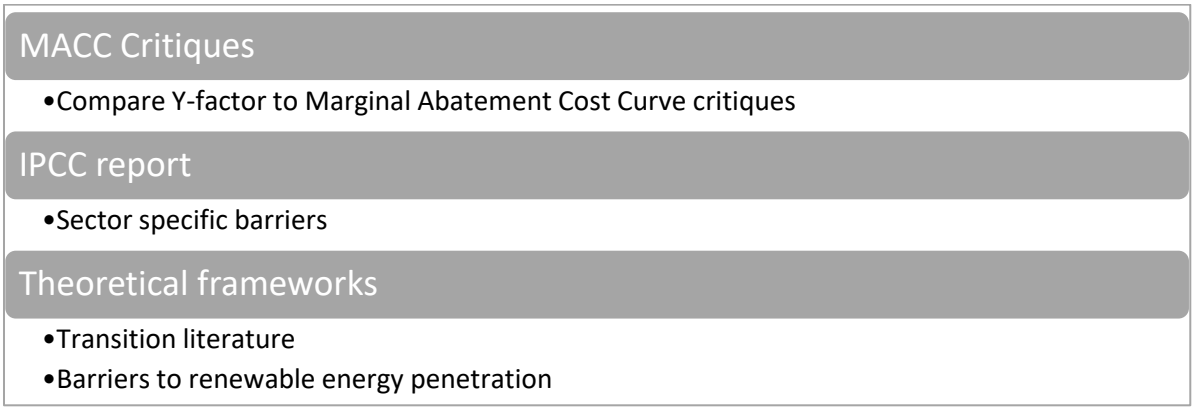

Figure 1.1 Overview literature review

1.3.2 Case study research with expert interviews

Expert interviews on four CO2 abatement options (cases) are conducted to deepen the understanding of the barriers of the Y-factor. Case study research is a suitable approach for this goal as it provides in-depth knowledge on a small domain (the selected CO2 abatement options) (Verschuren & Doorewaard, 2010). Expert interviews can provide a rich source of data for this goal. Experts can also reflect on the question if the full story of the abatement option can be told by discussing the barriers of the Y-factor. The cases are selected from the top fifty of CO2 abatement measures of the MACC of McKinsey (Nauclér & Enkvist, 2009). This is the same set as used by Chappin (2016). The barrier scores from his paper are used as input for the selection. This leads to the following research question:

2. What is a representative set of case studies for CO2 abatement in the Netherlands?

In the expert interviews, the focus is on finding the rationale behind the barrier scores to increase the understanding of the barrier. This makes comparison between interviewees possible as well as comparison between abatement options. The combination of the scores and the rationale make it possible to systematically show and analyse the hurdles to materialisation. This provides an answer to the following research question:

3. What are the Y-factor scores for the cases and what is the underlying rationale?

In the expert interviews the Y-factor is discussed with experts on different abatement options. This discussion naturally provides insight on the clarity of the definitions and the completeness of the Y-factor. With this information the following research question could be answered:

4. How can the Y-factor be improved based on the obtained insights?

Demarcation of the research

A case study based on expert interviews is a labour-intensive research method. Due to the time constraint of this research, the choice was made to investigate four abatement options. On one abatement option, three to four experts from different disciplines have been interviewed. Additionally, the geographical scope of this research is defined to the Netherlands and Dutch policy to demarcate the interview topic.

1.3.3 Research Flow Diagram

The connections between the different research questions and chapters is visualised in a research flow diagram. This is presented in figure 1.2.

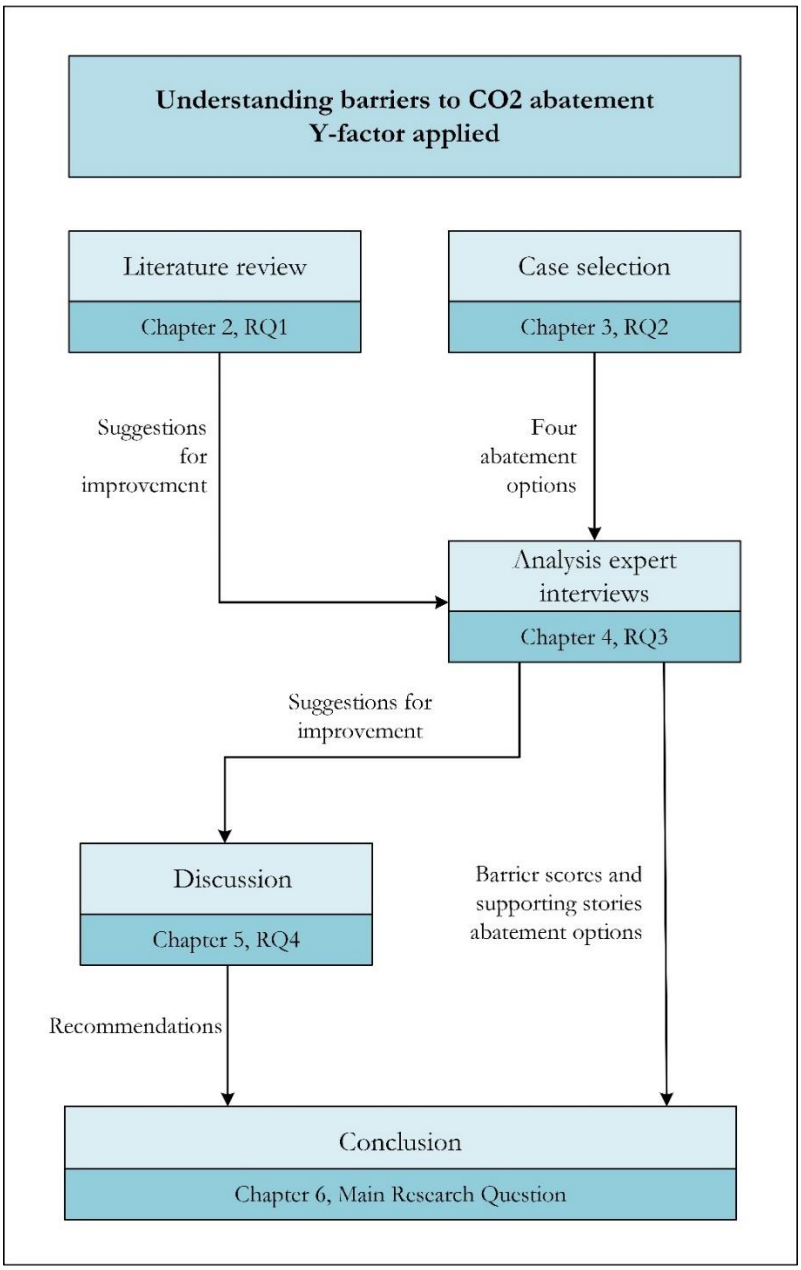

Figure 1.2 Research Flow Diagram

1.3.4 Y-factor definitions

Table 1.2 shows the existing definitions of the Y-factor barriers that are used in this thesis. The table can also be found in appendix D. These definitions have been constructed by Chappin for his reordering of the MACC in (Chappin, 2016). The values 0, 1 and 2, that are shown in table 1.1 are replaced by low, medium and high in this research. The categories and their barriers have also been labeled with a code (A1..D3) to make it easier to refer to these elements. The high score of A2 is adapted from '>20 years' to '>12 years' to avoid unclarity in the expert interviews.The addition of 'skills' to B3 resulting from the literature review is already presented in this table. In this thesis, 'abatement measures' that are mentioned in the table are referred to as 'abatement options'.

Table 1.2 Definitions of the Y-factor

A. Costs and financing	**Low**	**Medium**	**High**
A.1 Investment cost required	Absent	Medium	Large
Degree to which the investment in an abatement measure is significant			
A.2 Expected pay-back time at 0 euro/ton	< 5 years	5-12 years	>12 years
Expected time required to earn back the investment for an abatement measure			
A.3 Difficulty in financing investment	None	Medium	Large
The degree to which it is difficult to finance the abatement or attract appropriate financial means			
B. Multi-actor complexity	**Low**	**Medium**	**High**
B.1 Dependence on other actors	None	Few	Many
Degree of dependence on actions of other actors to successfully implement and execute the abatement measure			
B.2 Number of actors	Few	Many	Millions
Number of actors that are required to take action to realise the abatement measure			
B.3 Types of actors involved	Few	Medium	Many
Degree of diversity of interests, values, roles, skills and expectations of the actors involved			
B.4 Responsibility unclear	Clear	Slightly	Unclear
The extent to which it is clear which actor has the responsibility for the abatement measure			
C. Physical interdependencies	**Low**	**Medium**	**High**
C.1 Physical embeddedness	No	Medium	Strongly
Degree to which the abatement measure requires physical changes to the environment it is placed in			
C.2 Disturbs regular operation	No	Slightly	Strongly
Degree (duration, intensity) to which status quo/regular operation is disrupted to successfully apply the abatement measure			
C.3 Technology uncertainty	Fully proven	Small	Large
Degree to which the technological performance of the abatement measure is uncertain			
D. Behaviour	**Low**	**Medium**	**High**
D.1 Outside of thinking scope of actor	No	Partly related	Outside scope
Degree of awareness of the parties responsible for the abatement measure			
D.2 Frequency of opportunity	Often	Medium	Rarely
Number of opportunities for the responsible party to realise the abatement measure			
D.3 Requires change in behaviour	No	Slight	Severe
Degree to which the actors involved need to change their day to day behaviour			

2. Literature review

In this chapter the literature review is presented. The main aim of this review is to underpin the barriers of the Y-factor and to clarify the position of the Y-factor in literature on barriers to materialisation of CO_2 abatement options. In section 2.1 an overview of the literature review is presented including an explanation about its function. In section 2.2 the critiques of the Marginal abatement Cost Curve are used to test if these are answered by the Y-factor (as was claimed to be the goal by Chappin (2016). In section 2.3 the Y-factor barriers are compared to general barriers for abatement options through comparing the Y-factor to barriers from sectors in the IPCC-report (Intergovernmental Panel on Climate Change). Last, in section 2.4 the y-factor will be compared to theoretical frameworks in the field.

2.1 Overview literature review

This section provides information on the function of the literature review and underpins the chosen literature.

2.1.1 Function of the literature review

The goal of the literature review is twofold. First, an attempt is made to underpin the presented barriers of the Y-factor with literature. This also includes checking if some barriers for the materialisation of CO_2 abatement options are lacking. Second, the position of the Y-factor within the field of (sustainable) transitions is clarified by reviewing sources from different angles of this field. In figure 2.1 an overview of the chosen literature is shown.

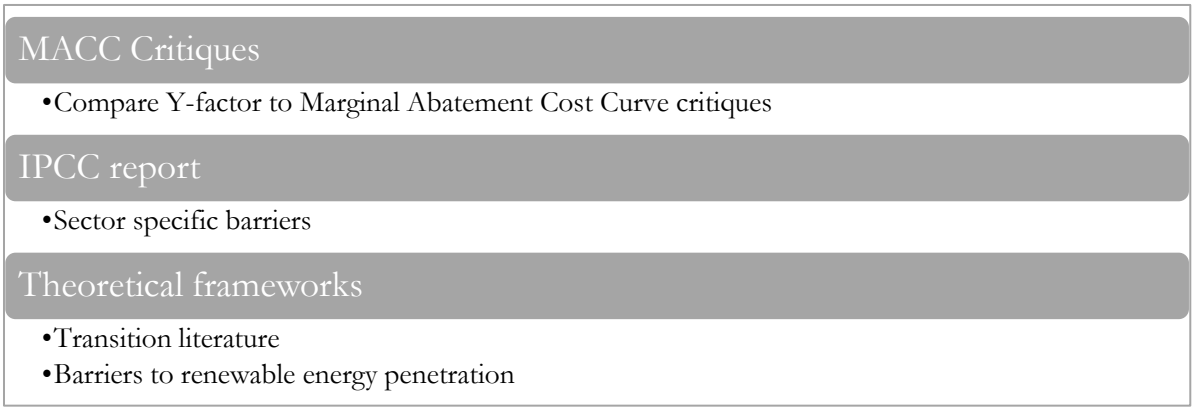

Figure 2.1 Overview literature review

2.1.2 Underpinning of selected literature

The Y-factor is a new method to provide insight into the analysis of CO_2 abatement options. This research field already exhibits several players: Institutions as well as literature streams.

First, the Y-factor is developed as a response to the only financially focussed MACC. This curve is critically reviewed in a report from University College Londen (Kesicki et Al., 2011). The Y-factor is contrasted with their critiques, to test if the Y-factor fills (part of) the gaps of the MACC.

Second, the IPCC (Intergovernmental Panel on Climate Change) is an internationally recognised institution which reports every six years on the status of Climate Change action in the world. This report reflects the view and knowledge of a large number of researchers. The report is structured by the sectors where CO_2 abatement is possible. In this review the most recent version of the report (from 2014) is used (Intergovernmental Panel on Climate Change [IPCC], 2014).

Third, transition literature is a field which studies the understanding and potential steering of transitions. This includes the analysis of the adoption of technological innovations as well as sustainability transitions. Another framework, of (Painuly, 2001), is discussed as well as it evaluates the barriers for the penetration of renewable energy technologies, which is comparable to the Y-factor. Appendix D shows the definitions of the Y-factor used in this research. References to the **categories** will be bold in this chapter, references to *barriers* will be in italics.

2.2 Marginal Abatement Cost Curve critics

The Y-factor was developed by Chappin (2016) to serve as a 'complementary analysis' to the Marginal Abatement Cost Curve (MACC). To underpin this statement, it is of interest to discuss which weaknesses of the MAC-curve are strengthened by the Y-factor analyses. The sources which provide critique on the MAC-curve are (Kesicki et al., 2011) and (Kesicki & Strachan, 2011). The first report focusses mainly on weaknesses of McKinsey's abatement (Nauclér & Enkvist, 2009), the second source discusses weaknesses of MAC-curves in a more generic manner.

2.2.1 Strength MACC reflects in Y-factor?

The summarising power of the MAC-curve reflects in the Y-factor curve as well as can be viewed from the Y-factor curve in (Chappin, 2016). In the MAC-curve different CO_2 abatement options can be compared with respect to their cost and potential. In the Y-factor different CO_2 abatement options can be compared on the type of barriers which have to be overcome for materialisation of the abatement option. This makes it easier for policy makers to make comparisons between different options on cost and potential as well as making comparisons between regions.

2.2.2 Unjustified scores of the MACC

A downside of the MAC-curve's summarising power is the both non-transparent assumptions and calculations that underpin the curve. Different levels of cost definitions can be used for the MACC, from narrow to wide: Project costs, technology cost, sector cost and macro-economic cost (Kesicki et al., 2011). McKinsey used the lowest cost level, which solely includes "the installation and operation of low-emission technology" in their calculations (Kesicki et al., 2011, p. 13). An average of different project costs is chosen in the calculation. Some other relevant assumptions which influence the outcome of the calculations are: the chosen discount rate and the choice of presenting costs for one year instead of accumulated costs over time (Kesicki & Strachan, 2011). The final score which is presented in the curve is the cost of implementation of X €/Mton CO_2 reduction. If the CO_2-price reaches this level (or the gap is filled with subsidy), the materialisation of the abatement option is expected to take place.

In the Y-factor three scoring categories (predominantly quantitative) are used per barrier. This differs from the MACC that uses more quantitative scoring. As the detailed assumptions and calculations are not available, the support for the scores is not transparent. The Y-factor table shows the barriers with its scoring categories, that show how the final barrier score is built up. A high score on one barrier, e.g. *pay-back period* does not have to be as difficult to overcome as a high score on another barrier e.g. *dependence on other actors*. It solely shows that both barriers have to be considered in the when aiming to stimulate the materialisation of an abatement option.

2.2.3 Weaknesses of the MACC

Next to the critics on the calculations which lead to the MACC, other weaknesses have been identified. These entail the lack of acknowledgement of: complexity, the interactions of abatement measures, a number of implementation barriers, intertemporal aspects and the creation of a false sense of certainty (Kesicki et al., 2011; Kesicki & Strachan, 2011). The last two critics have been discussed already. The first three critics will be discussed and confronted with the Y-factor.

Lack of showing complexity

The Y-factor evaluates the CO_2 abatement options from a system's perspective, considering costs and financing, multi-actor complexity, physical interdependencies and behaviour. This is a significantly wider perspective than the MACC, which describes the options from an economic perspective of cost and potential. If you want to include the fact that the system under study is complex, it is necessary to treat it as a system as well. This means studying it with a system's perspective where the interconnectedness of the different system elements is considered as well as interactions between the different elements.

The Y-factor provides this system's perspective through evaluating the measures with respect to a range of barriers in different categories. However, the interconnectedness of these system elements is not directly shown in the Y-factor. It is not possible to make a 'one-size-fits-all' structure for these interconnections, as these can be different in every abatement option. Combinations of certain barriers often occur together, which leads to a stronger or weaker barrier. An example is a high score on the *number of actors* (e.g. households) and a high score on *requires change in behaviour*. This leads to a stronger

barrier where many households have to make large changes (e.g. installation of new heating systems which run on electricity). The combination of these characteristics for an abatement option thus leads to a strong barrier. This understanding is important to develop effective policies to reduce the barriers.

The Y-factor does invite its users to think of links between barriers (and therewith system elements) more than the single score of the MAC analysis. This can open the discussion on which barriers are connected and should maybe be tackled together in a single approach. This holds when the scores for one abatement option on the different barriers is shown in the table, not when several options are visualised in the graph.

Implementation barriers

Kesicki and Ekins (2011) name a number of implementation barriers in their report as well. These will be discussed shortly before connecting these to the Y-factor. The first barrier is 'agency issues', the split incentive of the investor in (e.g. insulation) which does not get the financial benefit of this investment (as this results in a lower energy bill for the tenant). This barrier is a combination of the barriers *types of actors* involved and *difficulty in financing*. The diversity of interests lead to a difficulty in financing as the beneficiary is not the financing party. High scores on these two barriers reflect the existence of this issue. Through additional interventions the barriers may be reduced, e.g. subsidies for financing of the insulation costs.

The second barrier is 'information failure', which includes the transaction costs (mostly time costs) which must be made when implementing abatement options as well as the lack of awareness on the existence of options. This is mostly reflected in the Y-factor in the behaviour barrier *outside of thinking scope of actor. Dependency on other actors* for information or complicated permit procedures are components for information failure as well.

The third and fourth barriers are well-reflected in the Y-factor. 'Inertia', keeping the status quo, is reflected in the barrier of *disturbs regular operation* and *requires change in behaviour*. The barrier of financial hurdles is reflected by the full *costs and financing category*.

Last, however nonetheless important, is the phenomenon of 'path dependency'. This relates to high *investment costs* with long *payback periods* which are typical for investment in the energy industry. Next to the sunk costs, there is also a physical lock-in when infrastructure is built through the high *physical embeddedness* of infrastructures.

2.2.4 Conclusion comparison MAC-curve

The MACC is developed to compare abatement options with respect to their costs per Mton CO_2 reduction and their potential. The strength of this curve is its summarising power and practical use. However, critiques on this curve are present as well. The Y-factor is developed as a complementary analysis with the aim to take away some of the weaknesses of the financially focussed MACC.

They Y-factor uses a similar presentation as the MACC where the barrier scores are visualised. The Y-factor offers transparency on its method which leads to the scoring through the definition of thirteen barriers and their values. These also invite the user to use 'systems thinking' as a range of barriers is presented instead of solely the materialisation costs. The range of implementation barriers in the UCL report (Kesicki et al., 2011): (agency issues, information failure, inertia, financial hurdles and path dependency) are covered in the Y-factor. Often a combination of several barriers of the Y-factor results in the 'UCL barrier'.

2.3. General barrier literature: IPCC report

To provide a wide overview of the barriers for materialisation of CO_2 abatement options, the most recent IPCC (Intergovernmental Panel on Climate Change) report of 2014 was selected as a source to provide an overview of barriers in different sectors (Intergovernmental Panel on Climate Change, 2014). This report reflects the view and knowledge of a large number of researchers and is published approximately every six years.

2.3.1 IPCC report structure

The IPCC report is divided in sixteen chapters. Chapter seven until eleven are summarised in this literature review, as these chapters discuss sectors that relate to CO_2 emissions. Measures from these sectors are also part of the top 50 abatement measures from McKinsey's report which were analysed with the Y-factor method in (Chappin, 2016).

The sector-related chapters all have a similar header structure, with one header mentioning 'barriers'. However, the content under this header was not organised similarly in the chapters. There was a difference in level of detail, which resulted in barriers which are not straightforward to compare the thirteen Y-factor barriers. However, the mentioned barriers can be matched to the four main categories of the Y-factor. This categorisation is shown in table 2.1. The barriers are formulated in general phrasings as these where summarised in the report as representing the barriers in the sector.

Only chapter 8 about transport lacked a list of more general factors, the first three measures where thus included (as these are part of the top 50 measures of McKinsey (Nauclér & Enkvist, 2009)). The barriers which were specifically related to developing countries were left out of scope. These are mostly related to investments and the focus on short-term priorities for basic living conditions instead of long-term investments. Also, regulations are often less extensive in developing countries.

Table 2.1 Categorisation of barriers from (IPCC, 2014) per sector in Y-factor categories

Chapters IPCC (2014) ➡ Y-factor ⬇	7. Energy supply	8. Transport	9. Buildings	10. Industry	11. Agriculture
A. Cost and financing	-Capital intensive -Long pay-back periods	- High costs for biofuels and EV batteries - LNG: Insufficient government programmes	-Transaction costs - Limited capital - Lack of subsidies - Risk aversion - Externalities	- Regulatory frameworks and institutions that may enable investment - Cost of technology options and systems	-Accessibility to financing - Design and coverage of the financing mechanisms - Scale of financing
B. Multi-actor complexity	- Long procedures and regulations -Public acceptability problems -Uncertainty in policies	- No uniform EV recharging standards - LNG: Local gas markets have to be made	-Imperfect information - Principal-agent problems - Fragmented market and institutional structures - Difficulties concerning patent pro-tection and technology transfer	- Industrial organization-nal and behavioural barriers to implementing change - Market failures -Public acceptance	-Transparent and account-table governance and swift institutional establishment - Clear land tenure and land-use rights - Social acceptance

C. Physical interdependencies	-Lack of technology-specific infrastructure - Too low transmission capacity - Technological maturity	Electric vehicles: - Lack of infrastructure LNG: -Local gas Infrastructure needs to be built. - Leakage of gas	- Barriers depend on location and building type	- Maturity, reliability, safety, performance of technology - Gaps in information - Availability of infrastructure and space	-Variability in site-specific conditions - Generating, procuring, and applying science and technology to identify and solve an environmental problem
D. Behaviour	- Lack of awareness	-Electric vehicles: vehicle range anxiety	-Cultural aspects -Cognitive and behavioural patterns	- Cultural norms	-Cultural values
No fit with Y-factor categories	-Lack of skilled workforce		- Poor feedback - Poor enforcement of regulations	- Workforce capacity (e.g., education, training, and knowledge)	- Difficulties in monitoring, reporting, verification

2.3.2 Connecting Y-factor categories to IPCC sectoral barriers

Table 2.1 shows the categorisation of thy barriers from the IPCC-report in the Y-factor categories. This paragraph will discuss interesting notions on this categorisation.

For the **Cost and Financing** category, the barriers (*investment costs, pay-back period and financing difficulties*) are reflected in almost all sectors. Barriers on regulatory schemes/subsidies and are mentioned in the IPCC-report, which are not explicitly mentioned in the Y-factor.

The category **Multi-actor Complexity** (with barriers: *Dependence on other actors, number of actors, types of actors* and *responsibility unclear*) was not straightforward to recognise in the barriers of the different sectors. Barriers related to markets have been placed in this category, as many actors related to an abatement option are active on a market, e.g. regulators, suppliers or consumers. Institutional barriers are placed in this category as these are developed by (governments) or aimed at (market parties) actors related to the abatement option. Institutions can provide more clarity about the responsibilities of actors. 'Public acceptance' is placed in this category as it indicates diverse interests between actors.

The factors of the Y-factor are however not easily recognisable in the barriers of the IPCC report. They are mostly formulated on another, higher level. The market level, which is a result of the interactions of the actors. Regulations and procedures are set up institutions to steer and control the decisions and behaviour of the actors.

The category **Physical Interdependencies** consists of the barriers: *Physical embeddedness*, *disturbs regular operations* and *technology uncertainty*. Most barriers in the table (2.1) relate to the development of the technology. Lack of infrastructure is often mentioned as a barrier, which can be found in the Y-factor in barrier *disturbs regular operation*. Technology uncertainty is easily recognised in the IPCC-barriers.

The last category **Behaviour** consists of the factors: *Outside thinking scope of actor, frequency of opportunity* and *requires change in behaviour*. The barriers from the IPCC report mention culture (a large concept) as a barrier, which relates to the thinking scope of the actor and the change of behaviour barrier. The frequency of opportunity is not reflected in the barriers.

In the row **No fit with Y-factor categories**, a repeatedly mentioned barrier is the lack of skilled workforce. Other factors are difficulties in enforcing and controlling regulations. This can be due to lack of skilled personnel as well as physical obstacles for controlling, which is the case for the agricultural sector. In section 2.5, a reflection will be presented on candidates for additional barriers for the Y-factor.

2.3.3 Conclusion comparison to IPCC report

From the review it can be noted that it is difficult to categorise barriers. In the IPCC report this categorisation was performed differently for every sector. Besides, there was a lack of consistency in the words used for indicating similar barriers, e.g. cultural aspects, cultural values, cultural norms. This makes it more difficult to create a similar understanding on a concept. The IPCC report aimed to present the barriers in the same manner for every sector, however did not succeed completely. It shows that it was difficult to make a 'one-size-fits-all' solution.

The aim of this section was to underpin the barriers of the Y-factor. This was easily done for the Cost and Financing category. Multi-actor complexity was never explicitly named as a category, the factor *types of actors* (especially conflicts of interests) was reflected in literature. The other factors were only partly reflected. A reason may be that these factors are formulated on a more practical level for the Y-factor, indicating the source of the barrier. The barriers mentioned by IPCC were formulated on a more general, higher level. In the Physical interdependencies category, technological maturity was often mentioned as a barrier, the other factors were not mentioned in the wordings of the Y-factor. This may have a similar reason as the factors of the multi-actor complexity. The Behaviour category entailed mostly barriers related to culture.

2.4 Theoretical frameworks on transition

The Y-factor is not the first analysis scheme in the field of transitions. The field of transition studies discusses the mechanisms which play a role in transitions to a sustainable world (Lachman, 2013). In this section, the elements of the Multi-level perspective (MLP), Technological Innovation System (TIS) and Transition Management (TM) will be compared to the barriers of the Y-factor. In addition, the framework of (Painuly, 2001) will be discussed separately. The advantages and disadvantages of these frameworks will be confronted with the Y-factor, with the aim to clarify its place in the literature .

2.4.1 Transition literature selection

Lachman (2013) made a literature overview of the six most studied approaches in transition research. From these six approaches, the Multi-level Perspective (MLP) and the Technological innovation systems perspective (TIS) and Transition Management (TM) will be further analysed. The MLP is a well-known approach in transition literature. The Technological innovation systems approach provides another perspective through assessing the system weaknesses to clarify why innovations do or do not flourish. Transition Management (TM) is a governance model thus sheds a different light on influencing transitions.

The other approaches discussed by Lachman have been excluded from this comparison due the similar concepts in the frameworks (Strategic Niche Management shares concepts with MLP). The techno-economic paradigm and socio-metabolic transition approach are excluded due to their highly conceptual level and large time-scale which is not well comparable to the more specific Y-factor.

Technological Innovation Systems

The aim of the technological innovation system approach (TIS) is to increase the understanding of the emergence of new industries (Bergek et al., 2015). TIS-analysis can indicate the weaknesses of a technological innovation system, which block the development of innovations. It focusses on the fulfilment of certain functions in these systems such as: knowledge diffusion through networks, market formation and knowledge development (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). These seven functions are used in this section to compare TIS to the Y-factor.

The advantage of this approach is that it clearly pinpoints bottlenecks in innovation systems. The disadvantages are that there is a focus on large actors in these systems and culture and demand side aspects for the uptake of innovations are marginalised. The reasons behind the weaknesses are not well discussed, but only indicated (Lachman, 2013).

Multi-level perspective

The aim of the Multi-level perspective (MLP) is to increase the understanding of technological transitions (Geels, 2002). The basis of the MLP is the notion of landscapes (macro-level) and niches (micro-level) which interact with regimes (meso/sector-level). These levels change over time at a different pace .

The advantages of this perspective are that it provides a bird view and captures the complexity (numerous interactions) between and within the levels. It also acknowledges the system lock-in which leads to the resisting of change due to the current actor constellations, physical and market structures. Disadvantages are the use of 'imprecise concepts and metaphors' (Lachman, 2013, p. 272) and the fact that it is not straightforward to apply this perspective. As it includes such a large number of interactions, deciding on the 'correct' boundaries for analysis is challenging (Geels, 2002).

In the analysis of this chapter, the factors which describe the state of the meso-level in the MLP are used to compare to the Y-factor categories. These factors relate to developments on the sectoral level.

Transition Management

Transition Management is a governance model which argues for an integrated approach on three levels. The strategic level (long-term goal formulation), tactical level (coalition building) and the operational level (project building) (Kemp, Loorbach & Rotmans, 2007). This model is developed to tackle five key problems in the governance of (sustainability) transitions. The five key problems are (Loorbach, 2001):

- Dissent: different goals and means of actors
- Distributed control: every actor influences at different places in the system
- Determination of short-term steps
- Danger of lock-in: solution lock-in
- Political myopia: long-term policy should span over several political cycles

2.4.2 Comparison transition literature barriers to the Y-factor

In table 2.2 an overview is given of the topics of analysis which are present in the TIS, MLP and TM. These are matched with the categories as given by the Y-factor to check whether these theories can serve as a substantiation of the Y-factor categories. As the chosen approaches are of a more conceptual level than the Y-factor, the choice was made to compare the elements from these to the four Y-factor categories, instead of matching with the components of these categories. Some elements fit with more than one category of the Y-factor. These have been placed in the table twice. Some elements do not match with any of the Y-factor categories and are placed in a separate row.

Table 2.2 Comparing the Y-factor categories to transition literature approaches

Y-factor (categories)	**TIS,** functions from (Hekkert et al., 2007)	**MLP** factors from (Geels, 2002)	**TM** factors from (Loorbach, 2001)
Cost and financing	- Market formation - Resources mobilisation	- Markets, user practices	- Danger of lock-in
Multi-actor complexity	- Knowledge diffusion through networks - Creation of legitimacy/counteract resistance to change	- Industrial networks, strategic games	- Dissent - Distributed control
Physical interdependencies	- Knowledge development	-Infrastructure - Techno-scientific knowledge	- Danger of lock-in
Behaviour	- Market formation	-Markets and user practices	
Not captured in Y-factor categories	- Entrepreneurial activity - Guidance of the search	-Symbolic meaning of technologies -Sectoral Policy	- Determination of short-term steps - Political myopia

Some elements of approaches have been placed in two Y-factor categories. This demands a further explanation. The element *market formation* relates to *costs and financing*, as funding must be raised for entering the market, as well as it links to *behaviour,* as consumers have to change their behaviour in the use of this new 'measure' and there have to be sufficient opportunities to install the new measure. This is similar to the factor *markets and user practice*s of the MLP. The creation of legitimacy (TIS) could also be part of behaviour, as when change is required in the adaptation of a new measure, this is part of the behaviour of the actors. Last, *knowledge development* and *techno-scientific knowledge* are placed under *physical interdependencies*, as this Y-factor category includes technology uncertainty (thus the level of maturity of the technology). For TM, the *danger of lock-in* relates to the high costs of choosing an option as well as adapting the physical landscape, e.g. investments in infrastructure. Therefore, this problem is placed in both categories.

Not captured in Y-factor categories

Table 2.2 also shows several factors which cannot be categorised in the Y-factor categories. Several of these relate to topics related to institutions and the role of the government. From the MLP this is 'sectoral policy'; from TIS 'guidance of the search'; from TM 'determination of short-term steps' and 'political myopia'. This last factor entails the agreement on long-term goals from the government which aim to steer the development of technologies. These goals and policies also provide actors in the sector more security for their investments. This candidate factor 'lack of institutions' will be discussed in section 2.5.

Another factor which cannot be placed in the Y-factor categories is the 'symbolic meaning of technologies'. This means that technology/technological is used as a symbol for e.g. status (cars). Also, the entrepreneurial activity cannot be categorised easily. This relates partly to the costs and financing and technology uncertainty. It could as well be under multi-actor complexity, relating to the factor of *responsibility*

unclear. It this is the case there is not much drive for the entrepreneur to bring the technology forward. The entrepreneurial activity does not connect directly to characteristics of a measure, which is what is scored with the Y-factor.

2.4.3 Comparison to a barrier framework

To further underpin the categories of the Y-factor, another source which provides an overview of barriers was searched. This led to mostly case-based barrier identifications, although a comparison can only be made with another framework/method which also aims to identify barriers for a range of renewable energy measures. It is interesting to research how barriers are categorised in another framework/method, especially since the IPCC proved to be less structured than expected.

The framework of Painuly (2001) aims to make a categorisation of barriers for renewable energy penetration. He presented a division of seven categories: 1. Market failure/imperfection, 2. Market distortions, 3. Economic and Financial, 4. Institutional, 5. Technical, 6. Social, Cultural and Behavioural and 7. Other barriers. In the category 'institutions' several aspects related to stakeholder involvement and conflicts are named, however not explicitly dependence on other actors and number of actors. 'Public acceptance issues' are placed in the category of *Social, Cultural and Behavioural* barriers where it seems more logical in the Y-factor to place this in category B Multi-actor complexity, as it entails a conflict of interest. Several barriers relate to lack of information and information awareness. These substantiate the barrier *out of thinking scope of actor* of the Y-factor. It is interesting to notice that in the *Technical* category, the physical embeddedness is not mentioned as a barrier. This category mostly consists of barriers related to lack of skilled personnel or standardisation and certification.

The goal of Painuly's framework is to provide an extensive list of potential barriers for abatement options. It is up to the user of the framework to select relevant barriers for the abatement option under investigation and to further specify these barriers. Painuly (2001) makes some interesting remarks about his framework as well. He indicates that it is difficult to make a categorisation and notices that factors can sometimes fit more than one category. He brings forward that some factors may be related and even have cause-effect relations. This is an interesting notion to investigate further in the remainder of this research, as this can be the case for the Y-factor as well.

2.4.4 Conclusion: Comparing approaches to a method

In the multi-level perspective (MLP) and the technological innovation (TIS) systems approach), transitions are analysed from a more high-level perspective than the Y-factor analysis. The selected transition literature could be categorised as perspectives or approaches and the Y-factor as a research method. The elements in these analyses (the factors in table 2.2) are formulated in a more abstract manner (e.g. culture and industrial networks for MLP). Hence, the category level of the Y-factor compares to the level of analysis of MLP and TIS. The comparative analysis was thus executed on the category level of the Y-factor. The Transition Management approach is a governance model that focusses more on political decision-making in transitions, which is outside the scope of the Y-factor.

The MLP, TIS and TM approaches are more qualitative of nature than the Y-factor. In the Y-factor, the qualitative story behind the barrier must be translated in a low, medium or high score. This leads to a more content-focused underpinning since the height of the barrier must be supported as well.

In the framework of Painuly (2001) a categorisation into seven categories was made, however with the note that factors can often fit in more than one category. The framework of Painuly (2001) enumerates more categories and barriers than the Y-factor. This high number of 'comparing factors' can make it difficult to (visually) compare different abatement options in a structured manner. The user of Painuly's framework has to further define the relevant barriers itself and is given the option to attach an ordinal scale to indicate the relevance of the barriers. The difference with the Y-factor is thus that it is a more 'ready-to-use' method as well as it has the goal to compare abatement options while Painuly's framework intends to provide a complete identification of the barriers for an abatement option. It is, however, the most similar approach to the Y-factor from the literature review.

2.5 Reflection on candidate factors for the Y-factor

This review leads to a list of barriers that are not present in the Y-factor but are acknowledged as relevant barriers in the reviewed sources. This section reflects on the question if these barriers should be incorporated in the Y-factor.

- Lack of institutions

Barriers related to institutions and (long-term) policy are mentioned several times in the review. However, lack of institutions/policy in itself is not a barrier, the reason for the need for policy is the actual barrier. This is the focus of the Y-factor (e.g. a need for financial regulations, additional regulations to clarify the division of responsibilities). The lack of institutions would thus reflect in a high barrier score in the Y-factor on the barrier where interventions can be beneficial.

- Lack of skilled workforce

This candidate relates to the level of knowledge of both people who install equipment and the level of knowledge of policymakers and engineers. This factor can be placed under the *types of actors involved* when 'skills' is added as a type of diversity of actors. This will be added to the Y-factor in the remainder of this research.

- Public acceptance

The candidate of public acceptance overlaps with the factor *types of actors involved* as it indicates a conflict of interest. This factor is, however, a classic barrier for renewable energy. As it only relates to the conflict of interest between the initiator of a project and the citizens, it is chosen to not include it as a distinct barrier in this research in the multi-actor complexity category as this category entails the evaluation of all involved actors.

- Lack of infrastructure

This candidate shows the problem of an abatement option which can only flourish when relevant infrastructure is present. The *investment costs* are generally quite high (which reflects in the financial category). The *disturbance of regular operation* of the building of an infrastructure is generally high as well as long-distance structures under or above ground (*physical embeddedness)* are often needed.

2.6 Conclusion Literature review

The aim of this chapter was to research if the Y-factor barriers can be supported by literature relevant to materialisation barriers to CO_2 abatement. From this comparison it was also possible to clarify its place in literature on materialisation barriers.

Y-factor compared to MACC, IPCC-report and theoretical frameworks

The comparison of the Y-factor to the weaknesses of the financially focussed MACC shows that it complements this curve in several areas. It provides a transparent method on how the Y-factor score is built up. This method shows the range of barriers and also invites the user of the Y-factor to link different barriers (acknowledge complexity) although these links are not explicitly part of the Y-factor. Implementation barriers mentioned in the UCL report (Kesicki et al., 2011) are covered by combining several barriers of the Y-factor.

The IPCC report discusses barriers from different sectors. However, the report lacks consistency in using similar wordings for similar barriers. The barriers for different sectors differ in their level of detail and are hence not presented in the same manner. This shows it is difficult to find a 'one-size-fits-all' to compare abatement options with respect to their materialisation barriers.

Section 2.4 discussed theoretical framweorks: the multi-level perspective, technological innovation system, transition management and a framework on reneweable energy technology penetration. Especially the first three frameworks are formulated on a higher level than the Y-factor. This makes the defined units of these frameworks less comparable to the barriers of the Y-factor which are more specified. Therefore, it can be concluded that the Y-factor can be classified as a research method. Painuly (2001) shows an elaborate framework with more categories (seven) and many barriers per category (on average eight). This framework is due to its size and aim to be exhaustive, less suitable to systematically compare abatement options.

Potential candidates

Four potential barriers have been concluded from the literature review: Lack of institutions, lack of skills, public acceptance and lack of infrastructure. The latter two are reflected in a combination of the Y-factor barriers. 'Skills' will be added to the definition of barrier B3, types of actors, as it indicates a diversity amongst actors. The 'lack of institutions' is not incorporated in the Y-factor on purpose as institutions are viewed as interventions that can reduce barriers that are indicated by the Y-factor. The lack of institutions reflects in high scores for the barriers where additional intervention may be beneficial. For example, indistinctness of responsibilities indicates that regulations on this topic can be beneficial).

Lessons learnt

The Y-factor can be classified as a research method, since it is more concise and concrete than the frameworks it was compared to. The reviewed literature was formulated on a more conceptual level. Hence, the relevance of the four Y-factor categories could be supported by the reviewed literature. The thirteen barriers could not be supported individually.

3. Method

This chapter discusses the methods used in this research. First, four cases are selected to be able to apply the Y-factor in expert interviews on abatement options. The selection procedure is presented in this chapter. This is followed by small introductions to the cases indicating their potential and demarcation. In section 3.4 the interview setup is presented as well as the interviewees for this study.

3.1 Abatement options selection procedure

In this section, the abatement option selection procedure is presented and applied. The initial set of cases to choose from is provided by Chappin's (2016) selection of the fifty cheapest CO_2 abatement options based on McKinsey's MACC (Nauclér & Enkvist, 2009). The Y-factor scores that were used by Chappin for these of these options are used to rank these according to their barrier scores. In the selection procedure, the options will be presented in the following layout: Abatement category: abatement option [Y-factor score]. The selection procedure is visualised in figure 3.1

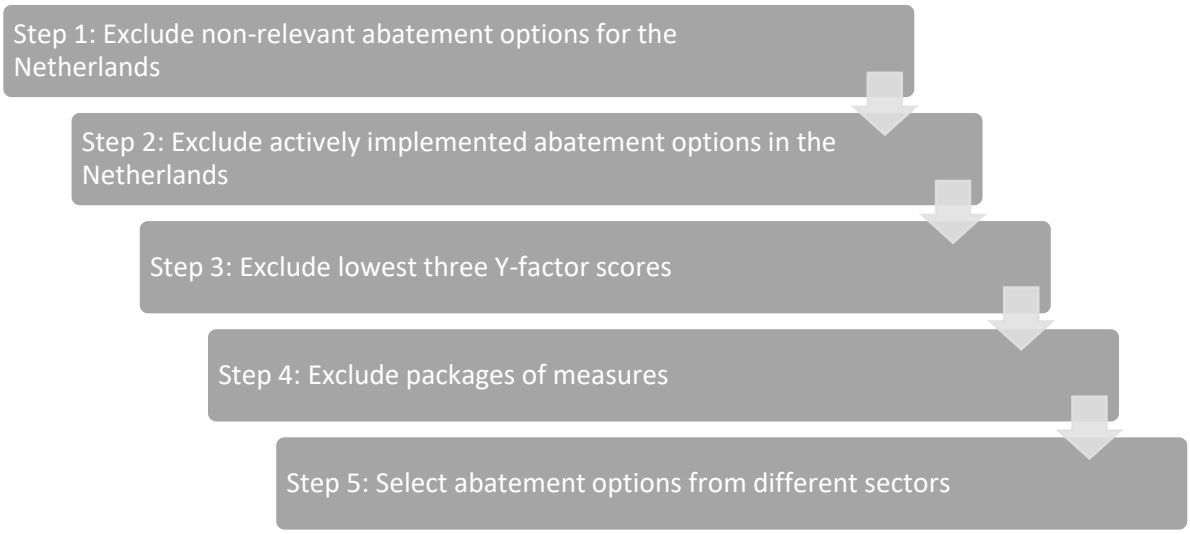

Figure 3.1 Abatement option selection procedure

Step 1: Exclude non-relevant abatement options for the Netherlands

In the remainder of this research, experts will be interviewed test the Y-factor in practice and to collect interventions for the barriers in the different cases. This led to scoping this research to the Netherlands. In this step the following options are excluded:

Energy: Small hydro [7], Solar CSP [9], Nuclear [16] ; Agriculture: Rice management [8], Reduced slash and burn agriculture conversion [17] ; Industrial processes: Clinker substitution by flay ash [12] ; Vehicles: Air transport [18] ; Forestry: Forrest management [13], Pastureland afforestation [16], Nuclear [16], Degraded forest reforestation [16], Reduced slash and burn agriculture conversion [17], Reduced deforestation from pastureland conversion [17], Reduced deforestation from timber harvesting [17]

Step 2: Exclude actively implemented abatement options in the Netherlands

Actively implemented abatement options have overcome the barriers for implementation, although they do indicate barriers through their scores. Abatement options which are not yet at this stage are more interesting to research as these indicate implementation problems.

Energy: Low penetration wind [10], PV panels homes [10], High penetration wind [11]; Waste: Electricity from landfill gas [10]

In 2016 57% of the subsidy was spent on wind projects (both on land and at sea), the expenses for solar PV almost doubled relative to 2015 (Rijksoverheid, 2017a). Using waste for energy production is also already developed in the Netherlands, concluded from various types of energy production of the association for waste processing companies (Vereniging Afvalbedrijven, 2018).

Step 3: Exclude lowest three Y-factor scores
Abatement options with Y-factor scores are less likely to have a wide range of implementation barriers. This does not contribute to covering all the Y-factor barriers in this research.
Households: Lighting switch incandescent to LED (residential) [5], Residential electronics [8]
Residential appliances [8]; Agriculture: Cropland nutrient management [8], Grassland management [8], Agronomy practices [8]; Vehicles: Motor system efficiency new build [8]

Step 4: Exclude packages of measures
Some of the abatement options consist of packages of smaller measures. To be able to perform clear interviews, the scope of the abatement option should be clear. Therefore, abatement options which consist of packages of measures are excluded.
Buildings: Building envelop package 2 residential [14]; Energy: LDV gasoline bundle 3 [9], LDV gasoline bundle 4 [9]; Industrial processes: Energy efficiency 1 Iron & steel [9], Efficiency improvements other industry [13]

Step 5: Select abatement options from different sectors
At this point, approximately half of the cases is excluded, which would make the others suitable candidates. Researching more than twenty cases is not feasible within the timeframe of this study.
The selection is based on picking diverse cases, thus from different sectors. The first two picks are cases with high scores [18] which also showed a similarity in barriers. These are **Carbon Capture Storage** (for coal plants) and **Geothermal energy.** To complement this selection, options from the building sector and fuel sector have been selected, namely**: Insulation in the residential sector** [17] and **Biofuels[1][**9]. The inclusion of these cases increases the generalisability of the results for a couple of reasons. The insulation case characterises itself by the large number of actors which have to take action. The biofuel case shows a lower overall score, which makes it possible to test if abatement options with a lower score show a different story about their implementation hurdles and potentially have different kinds of policy in place to reduce the barriers.

Cases which are similar to the selected cases are:
CCS: Coal CCS new build [17], Iron and steel new build CCS [17], Gas plant CCS retrofit [18], Iron and steel retrofit CCS [18], CCS direct energy retrofit [18]; Buildings: Insulation retrofit commercial [16].

The cases which are not selected are:
Agriculture: Tillage and residue management [10], Organic soil restauration [16], Degraded land restauration [16], Lifestock anti methanogen vaccine [16], Reduced intensive agriculture conversion [17]; Buildings: Building efficiency new build [10], Efficiency package new build commercial [13], Motor systems efficiency (retrofit) [10]; Vehicles: Cars full hybrid [10], Cars plug-in hybrid [13]; Waste: Composting new waste [11], Waste recycling [13]

3.2 Selection procedure underpinning
The case selection procedure of section 3.1 is a combination of selection strategies from the case selection review paper of Seawright and Gerring (2008).

The first strategy that was applied in the procedure was using predetermined criteria for selection. These criteria were used in step one to four. The goal was to exclude abatement options that are not relevant for the Netherlands and/or do not show clear implementation problems. In the fifth step, multiple strategies were used to 'steer' the handpicking process. This was a combination of the diverse strategy (selecting cases from different sectors), most-similar (similarity in Y-factor scores and both high scores) and most-different (no similarity in Y-factor scores and a larger difference in scores).

The most-similar strategy was used to select the Geothermal energy and Carbon capture storage cases.

[1] Biofuels was translated from the original abatement option *bio-ethanol lignocellulosic* (a 2nd generation biofuel). The biofuel case is scoped to 2nd generation biofuels for transportation. 2nd generation biofuels are generated from non-edible biomass.

Their similarity is shown in figure 3.2. The goal of the similar cases is to find out whether the similar barrier scores indicate similar background stories. Are the stories behind the scores as similar as the Y-factor suggests?

The most-different strategy was used to select the Insulation and Biofuel cases. The difference is found in this selection by looking for abatement options with different scores on the Y-factor components. An example is the score on the physical interdependencies category. The low or high scores indicate a difference (e.g. insulation directly affects the environment of households, biofuels bring fewer changes to the direct environment). This strategy is relevant to test the usefulness of the Y-factor for different compositions of the Y-factor. The differences between the Y-factor scores in the cases is shown in figure 3.3.

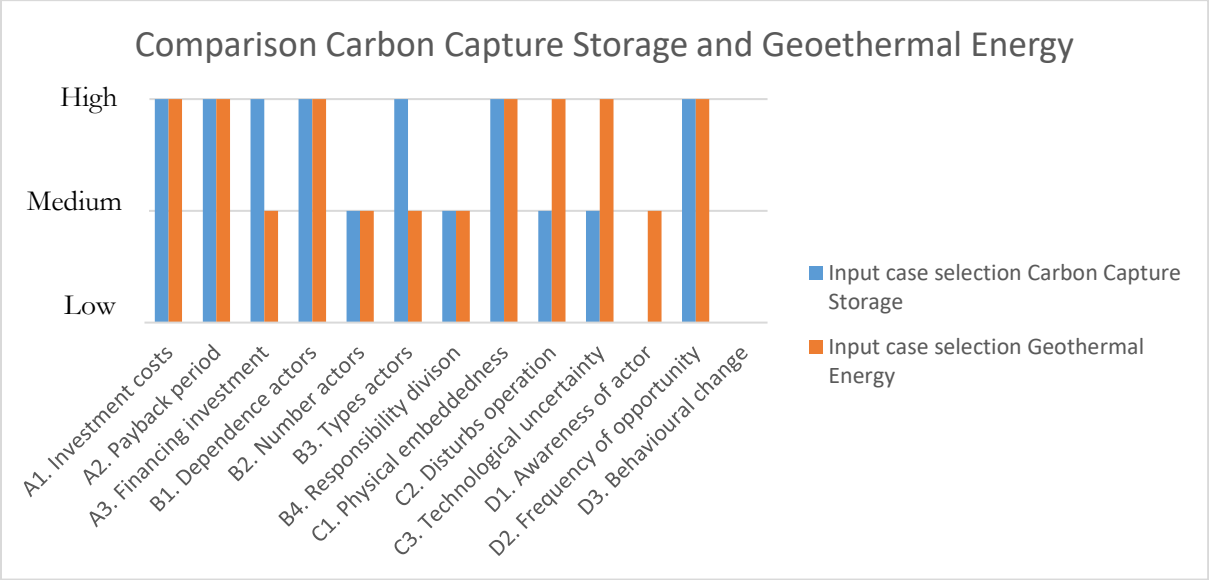

Figure 3.2 Most-similar abatement options

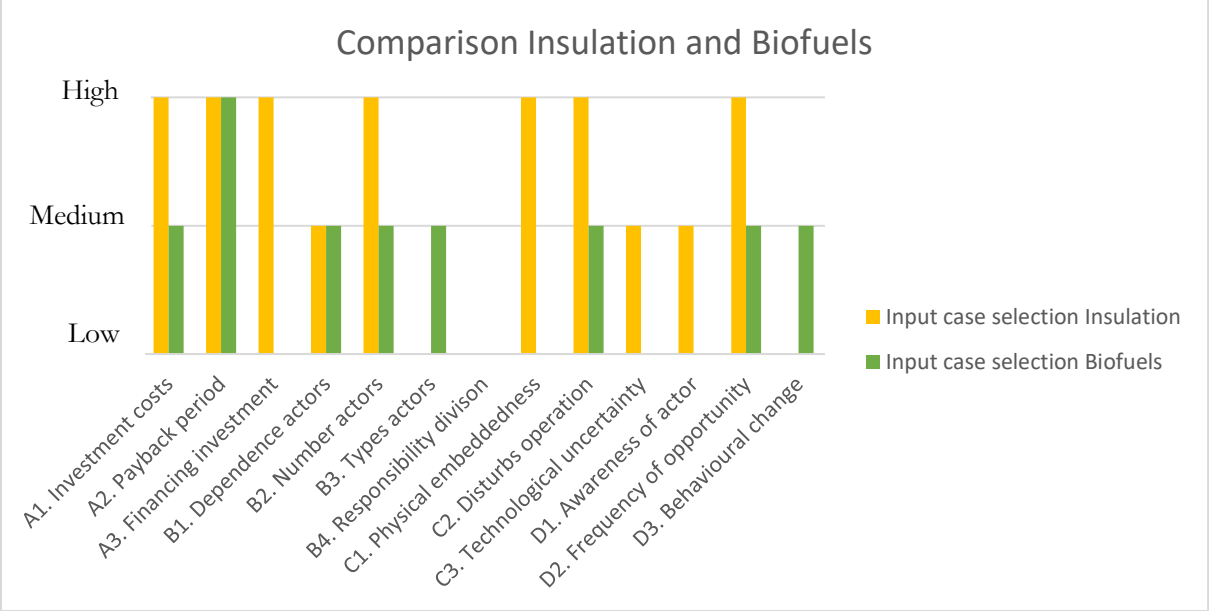

Figure 3.3 Most-different abatement options

In figure 3.4, it is shown the selection strategy lead to a package of abatement options that covers all barriers. This means the full Y-factor can be tested by investigating these abatement options.

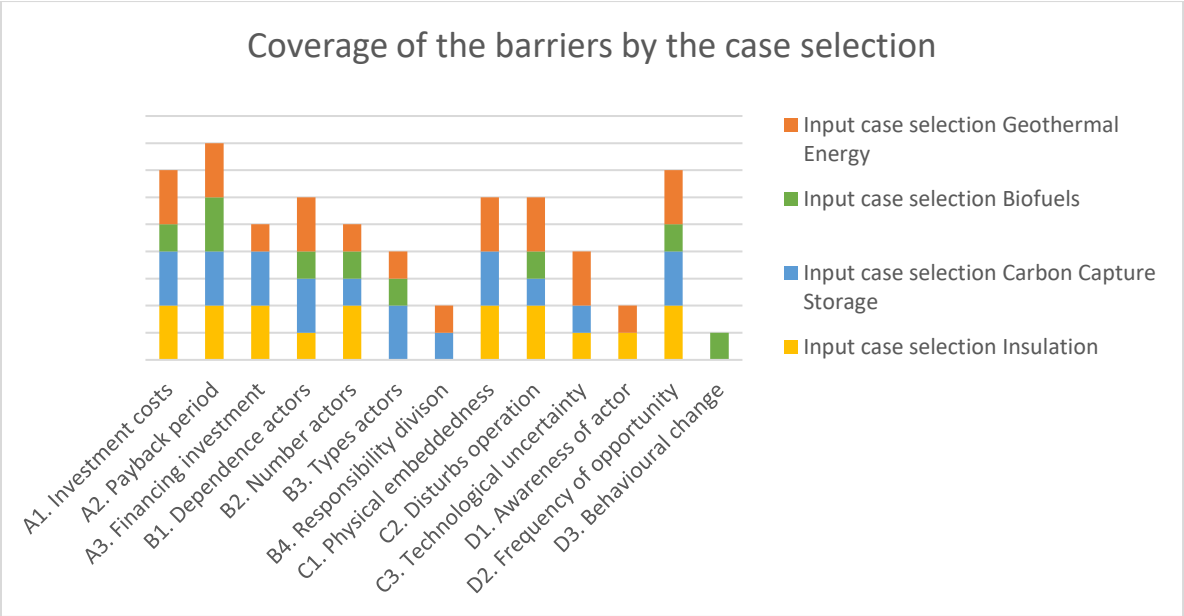

Figure 3.4 Coverage of the barriers by the case selection

3.3 Representativeness of the case selection

The representativeness of cases for the population (here fifty cheapest CO_2 abatement options) is important for the generalisation of the conclusions from the case study (Seawright & Gerring, 2008). The cases are of the types most-similar (figure 3.2) and most-different (figure 3.3). The most-similar abatement options both have high Y-factor scores and can thus be used to draw conclusions which hold for abatement options with high Y-factors scores as well. Conclusions on similarity of the barriers in practice (thus e.g. actual story of the multi-actor complexity) can be drawn as well due to the similarity of these cases. It should be checked carefully to what extent the exact characteristics of these cases influence the extent to which generalisation of conclusions is possible. The most-different cases have a high and medium Y-factor score and thus cover a larger range of abatement options. The diversity of abatement options (from different sectors) also contributes to the generalisability of the study.

3.4 Potential, current development and demarcation of abatement options

In the selection procedure, the Y-factor scores from Chappin (2016) have been used to indicate the barrier levels for the different abatement options. As Chappin indicates, barriers can differ widely over regions. A choice for Europe or the Netherlands was made when the scores had to be more specific. In this section, the potential of the selected abatement options is discussed, as well as the current state of implementation. The demarcation of the abatement options is presented as well. The geographical scope for all abatement options is the Netherlands.

Insulation

The total energy use of the built environment by households is 22% of the final energy use (approximately 400 PJ per year) (RVO, 2017). Approximately 70% of the energy is used for heating of space (mostly with natural gas). An energy reduction potential of 61 PJ in 2020 is estimated, when all houses that are built before 1995 are insulated (around 4 million houses) (van den Wijngaart, Folkert, & Elzenga, 2012). Since 2014, the yearly number of private home-owners that have taken energy saving measures is around five hundred thousand. No acceleration has started from awareness campaigns, energy-saving information points and subsidies. (ECN, 2017).

The abatement option 'insulation' is demarcated to residential housing with a focus on private home-owners that have a cavity wall and floor insulation possibilities. The insulation of commercial buildings is outside the scope of this case as companies most likely have different decision-making procedures and motivations for taking insulation measures.

Carbon Capture Storage

The potential emission reduction for CCS-projects in the Netherlands is estimated at 20 Mton CO_2 in 2030 (Koelemeijer, Koutstaal, Daniëls, & Boot, 2017) . This is mostly confined by the speed to implement CCS-projects, not by the availability of CO_2 to capture. In the government agreement, the goal for reductions by CCS in industry is set to 18 Mton in 2030 (Rijksoverheid, 2017b). This is almost one third of the total amount of CO_2 emissions that is aimed to be reduced in 2030 by this government agreement.

Currently, no Carbon Capture Storage project has been realised in the Netherlands, in Europe only two small storages in Norway are present (Global CCS institute, 2018). In September 2017, a large demonstration project in the Harbour of Rotterdam came to an end due to a lacking business case (Kamp, 2017).

This case is demarcated to projects initiated by industrial networks and/or parties. The focus is on the full chain of Carbon Capture Storage, hence including capturing CO_2, transportation and storage with a focus on offshore storage. The capturing of CO_2 focusses on coal power plants.

Biofuels

The energy use in domestic transport was 493 PJ in 2016 (ECN, 2017). Gasoline and diesel are the source for 96% of the energy use in this sector. Only 2% originated from the use of biofuels. The CO_2-intensity of biofuels is substantially lower than the CO_2-intensity of fossil fuels. Recent European guidelines demand a reduction of 70% of CO_2 emissions from biofuels in comparison to fossil fuels. With the current European regulations on blending biofuels with fossil fuels, the percentage of biofuels in transport will be 7% in 2030.

The abatement option 'biofuels' is scoped to the use for private cars. Biofuels are demarcated as fuels with a high percentage of bio-based raw material. The focus is not on higher blends of biofuels in conventional gasoline.

Geothermal energy

The potential for geothermal energy is estimated to be 25 to 50 PJ in 2040 (Van den Wijngaart et al., 2012). The ministry of Economic Affairs and Climate aims for 15 PJ of geothermal energy production in 2030. This is a substantial part of the average yearly heat demand from greenhouses and the built environment, which was approximately 460 PJ in 2016 (Wiebes, 2018).

The number of geothermal energy sources has been increasing over the last years, from two in 2008 to twenty in 2018 and adds up to 3 PJ (Platform Geothermie, 2018). The government offers financial support for the development of geothermal projects through a production subsidy (SDE+) and a fund where a part of the loss from miss drillings is compensated (Rijksoverheid, 2018).

This case is demarcated to horticulturists that change to geothermal energy for heating their greenhouse. The projects take place in a horticultural environment.

3.5 Applying the Y-factor in expert interviews

In this section, the selection of interviewees and the protocol of the interviews are presented.

Aim of the interviews

By discussing the barriers of the selected abatement options, it is the aim to create a full picture of the issues that impede the abatement option from flourishing in the Netherlands. It is the goal to see if the Y-factor entails the topics that can create this full story. A second goal is to deepen the understanding of the Y-factor barriers itself and with respect to links between barriers, completeness, stability of barriers and interventions to reduce barriers.

Selection of experts

For the expert interviews, Dutch experts with different backgrounds have been selected. Some have policy background or a research background while others are leading knowledge platforms or come from the business side. This diverse group could provide a wide overview of the barriers for the discussed abatement options and can reflect on the clarity of the barriers from different angles. Due to time constraints of this research, three or four experts have been interviewed per abatement option. To avoid a bias due to learning effects on the use of the Y-factor, the interviews of one abatement options were not performed consecutively. In table 3.1 the interviewees are presented. In the remainder of the research, these are referred to with the number that is indicated in the column next to their names.

Table 3.1 Overview experts per abatement option

Date interview	Name + reference number interviewee		Organisation	Type of organisation
Insulation				
14-2-2018	Rens Schipper	1	Energy Cooperation Zoetermeer (DeZo)	Knowledge platform
23-2-2018	Eefje Stutvoet	2	TU Delft, EnergieSprong	Academia
7-3-2018	Marianne de Snoo	3	Municipality of Rotterdam	Government
Carbon Capture Storage				
21-2-2018	Emma ter Mors	4	University of Leiden, CATO (CCS research project)	Academia
27-2-2018	Onno Tillema	5	ROAD-project CO_2-capture and storage in Rotterdam Harbour / ENGIE	Business
2-3-2018	Suzanne Brunsting	6	Energy Research Centre of the Netherlands (ECN)	Research
14-3-2018	Joëlle Rekers en Jeroen Bruijn	7	Ministry of Economic Affairs and Climate	Government
Biofuels				
22-2-2018	Saeda Moorman	8	Knowledge institution for Mobility (KiM)	Policy research
1-3-2018	Eric van den Heuvel	9	Platform Duurzame Biobrandstoffen	Knowledge platform
7-3-2018	Anouk van Grinsven	10	CE Delft	Policy research
Geothermal Energy				
20-2-2018	Martin Hogeboom	11	Trias Westland (Ultra deep Geothermal project)	Business
27-2-2018	Frank Schoof	12	Platform Geothermie	Knowledge platform
8-3-2018	Mike Woning	13	Deltares, Delft Aardwarmte Project	Knowledge platform
9-3-2018	Mara van Eck - van der Sluijs	14	DAGO (Dutch Association Geothermal Operators)	Branche organisation

Interview protocol
The interview process was performed as follows:
- Two days before the interview took place, the Y-factor table with definitions (see appendix D) was sent to the interviewee. The interviewee was asked to choose for each barrier if it was low, medium or high in the discussed abatement option. The goal of this preparation was to make the interviewee acquainted with the barriers and definitions of the Y-factor before the interview.
- The interviews have been conducted in a face-to-face setting. Each interview started with a short introduction of the research and explanation about the scoping of the discussed abatement option. Each interview was recorded and lasted approximately one hour.

During the semi-structured interview, the following questions were asked (translated from Dutch):
1. What is your position/experience in the field of the abatement option?
2. Did you think the factors were clearly formulated? If not, on which one(s) should I provide some extra explanation?
3. Did you miss any factor/barrier which is present for the abatement option?
4. Could you explain for each factor the rationale/story behind your choice for the barrier score?
5. Could you grade (between 1 and 10) the thirteen factors on the extent to which the factor is obstructing for this abatement option to flourish/start a project?
6. Are there any links between barriers according to you? (The interviewer also made notes on factors which were linked in answers to question 4).
7. Could you indicate the differences between the current difficulty of the barriers compared to ten years ago? (Per category)
8. Which intervention can be made to influence barriers? (The interviewer also made notes on interventions that were mentioned in answers to question 4).

- The recorded interview was used to summarise the answers of the interviewee. This summary was sent to the interviewee for revision and approval. The language of the interview itself and the summaries is Dutch. The interview reports can be found in appendix B.

3.6 Conclusion Method
This chapter describes the case selection procedure and the interview protocol.

Selected abatement options
The cases in this study are CO_2 abatement options scoped to the Netherlands. The selected cases are:
- Insulation: Focus on private home owners and houses with cavity wall and floor insulation possibilities
- Carbon Capture Storage: Focussed on industrial parties/networks and full-chain projects of CO_2 capturing, transport and (offshore) storage
- Biofuels: Focus on private car owners and biofuels with a high percentage of bio-based raw material
- Geothermal Energy: Focus on horticulturists as project initiators that change to geothermal energy for heating their greenhouses

The selection of cases covers all barriers of the Y-factor and entails abatement options from different sectors. Carbon Capture Storage and Geothermal energy show many similar barriers and biofuels show more differences with respect to their barriers. This leads to a selection from which more general conclusions on the use of the Y-factor can be drawn.

Expert interviews
By discussing the barriers of the selected abatement options, it is the aim to create a full picture of the issues that impede the abatement option from flourishing in the Netherlands. It is the goal to see if the Y-factor entails the topics that can create this full story. A second goal is to deepen the understanding of the Y-factor barriers itself and the clarity of the Y-factor definitions.

To reach these goals, experts with different backgrounds have been selected. In the interviews, the barriers of the Y-factor for each abatement option are discussed as well as their stability, missing barriers, links between barriers and current and potential interventions to reduce barriers.

4. Results

This chapter presents the barriers to materialisation of the four selected abatement options. This is described by using the Y-factor barriers and the Y-factor scores that were given by the interviewees. The content of this chapter is based on an analysis of the interview reports (appendix B) from the total of fourteen expert interviews on the four researched abatement options. First some additional explanation will be provided for clarification (4.1). This is followed by the description of the four abatement options in section 4.2, 4.3, 4.4 and 4.5. The chapter is concluded with comparisons between abatement options in section 4.6.

4.1 Introduction Results

Before describing the abatement options, some additional explanation is needed on definitions and scoping.

Definitions

Abatement option: Technologies implemented in the shape of projects to reduce the exhaust of CO_2.
Barrier: The thirteen factors as defined in the Y-factor table (A1 … D3) (Appendix D).
Intervention: Action, agreement or policy measure with the aim to reduce barriers that impede materialisation of an abatement option
Methodological insights: New information on the definitions of the barriers in the Y-factor and options for clarification of its use
Uncertainty: Variation in barrier scores provided by the interviewees of one abatement option

Scoping abatement options

All abatement options are geographically scoped to the Netherlands, as the experts are all working in the Netherlands.
Insulation (4.2): Insulation in residential area initiated by private home owners. The focus is on houses where cavity wall insulation and floor insulation are possible.
Carbon Capture and Storage (4.3): The capturing of CO_2, transport of CO_2 by a pipeline or network and storage of CO_2 with a focus on offshore storage. The initiating party that is focussed on is industrial networks and/or parties.
Biofuels (4.4): The use of biofuels for transport by private car owners. Biofuels are demarcated as fuels with a high percentage of bio-based raw material. The focus is not on higher blends of biofuels in conventional gasoline.
Geothermal Energy (4.5): Focus on horticulturists as project initiators that change to geothermal energy for heating their greenhouses

Interview reports

In appendix B, Dutch interview reports of the expert interviews are presented. These reports have been approved by the interviewees. The quotes in this thesis are translated quotes and therefore may have a slightly different tone than intended by the interviewee. Interviewees are referred to as interviewee 1 .. 14, the full list of interviewees can also be found in appendix B. The interviewees were asked to mention current and potential interventions, therefore the list per abatement option is an inventory and not exhaustive. The connection of interventions to different barriers was performed by the author.

Variance in scoring amongst interviewees

The experts of the abatement options provided different arguments for their scores. This led to variance in the barrier scores. The following method was used to conclude final scores for the four abatement options.

If possible, the mode was chosen as the final barrier score (for the scores 'low, low, medium', low was concluded). In-between scores' (low/medium or medium/high) were rounded up or down towards the mode. If this did not lead to a clear result, the score was derived from the background stories of the interviewees by the author. This is discussed in appendix C.1. The scores of all interviewees are presented in the sections on the abatement options in this chapter.

The variance in scoring is translated into low and high uncertainty. Low uncertainty means that one interviewee deviates from the scores of other interviewees (e.g. low, medium, medium). A high uncertainty means that more than one interviewee deviates from the most mentioned barrier score (the mode).

Several interviewees mentioned that it was difficult for them to select scores while not comparing the discussed abatement options to other options. This also led to the 'in-between scores' (e.g. Low/Medium) that cause some noise in the results. The 'in-between scores' are not noted as a deviation but rounded up or down to the mode. The sources of uncertainty will be further illustrated and categorised in the description of the abatement options.

Explanation high, medium, low barriers

In this chapter, the Y-factor barriers for the different abatement options are scored as 'high' 'medium' and 'low'. These scores refer to the definitions of the different barriers which can be found in appendix D. A low score indicates that the barrier is absent, a medium score that it is present and should be considered. A high score indicates that this is a relevant barrier that blocks the materialisation of the abatement option. The summarised interviews support the barrier scores in this chapter and illustrate the meaning of the score for the researched abatement options.

Reading guide description abatement options

In section 4.2 up until 4.5, the summaries of the analysis of the interview reports is presented. Each section starts by the illustration of the barrier scores. This is followed by a narrative that supports these scores. The narrative also provides ample insight into the meaning of the barriers within the abatement options. The variation in scoring is discussed by indicating and underpinning the source of uncertainty. Next, missing barriers, links between barriers and a reflection on changes in barriers in the past decade are presented. This is followed by an inventory of interventions to reduce barriers. Each section concludes with methodological insights into either barrier definitions or the application of the Y-factor. In section 4.6 the abatement options are compared using these same topics to conclude more general insights.

4.2 Insulation

This section describes the information gathered in the interviews regarding the barriers that households perceive for insulating their house. The defined scope is households which own a house with a cavity wall and a crawl space where wall and floor insulation can be added. In appendix B.1 the interview reports of the three experts can be found.

Figure 4.1 shows the scores provided by the interviewees to rate the barriers. Three barriers were rated with a high score: The number of actors (B2), types of actors (B3) and the awareness of actors (D1). The combination of these barriers describes the crux of this case: How to convince a large number of diverse households to take action? The story behind the other factors will be further elaborated on in this section.

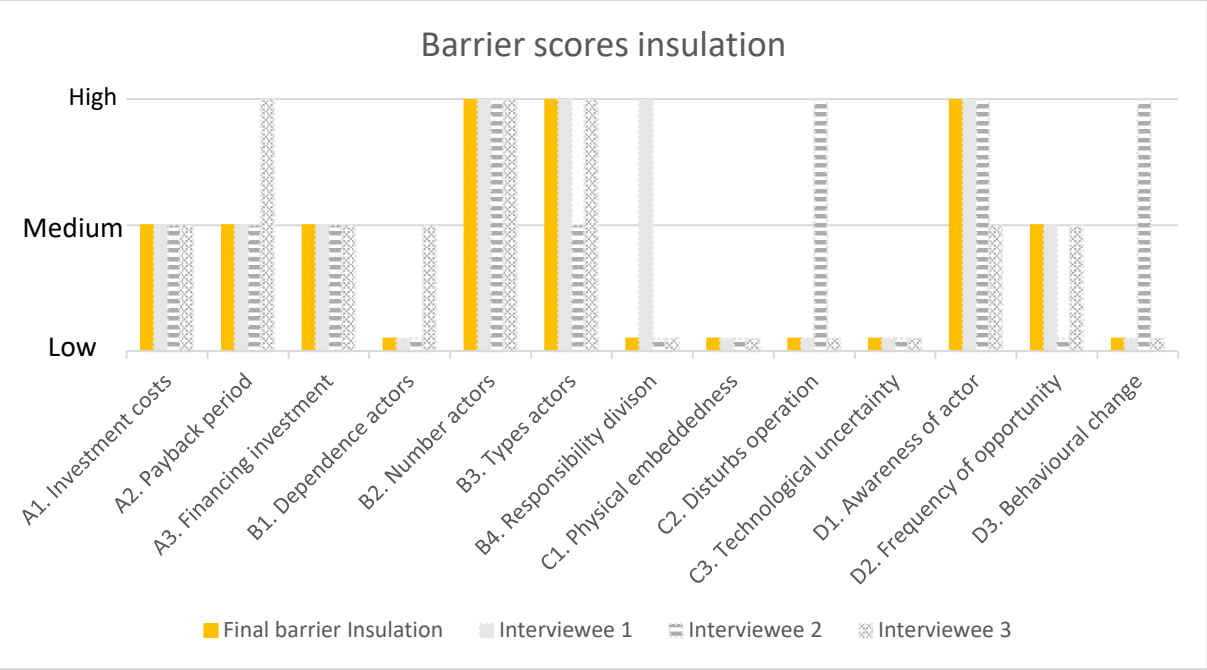

Figure 4.1 Insulation barrier scores

Barriers to insulation

Category A :Costs and Financing

The interviewees were in agreement about the barriers households perceive in the costs of insulation. Investment costs (A1) are an important factor in the decision-making process, but according to the interviewees surmountable. Two interviewees (1 and 3) mention the consideration households have with the payback period (A2): 'Will I live in this house in five years?' Interviewee 2 mentions in relation to the payback period: 'insulation measures are often taken from a comfort-driven rather than a financial motivation'. The difficulty in financing of investment (A3) depends on the financial reserves of the household. 'Subsidy options differ per municipality (interviewee 1), 'it is difficult to get a clear overview of the options' (interviewee 3).

Category B: Multi-actor Complexity

This category shows a larger difference in barrier scores than the previous category. The household can take the decision to insulate its house by itself (B1), it depends, according to the interviewees, only on a constructor and possibly an advising party or municipality. Interviewee 3 adds that a household which joins a 'collective purchasing action' (for a reduced price) depends on the decisions of other households. This is similar to tenants that depend on actions of their housing cooperation, which resulted in the medium score. The number of actors (B2) which should take insulation measures to reach substantial CO_2 emission reduction is a high barrier, 'millions of households should be convinced' (interviewee 3). The types of actors (B3) are diverse, there is a large heterogeneity in the motivations of households to insulate their houses (interviewee 1 and 3). It is also difficult to know which contractor is trustworthy (interviewee 2). Within associations of owners (Dutch: Verenigingen van Eigenaren), the diversity of households is also

large (interviewee 2). The interviewees gave different interpretations for factor B4 (responsibility unclear). Interviewee 2 argues that there is a difference between the stated intentions of households and their actual actions. Interviewee 1 discusses this factor on a higher scale level. 'Citizens point to the government for climate action, the government points to the market and tries to stimulate it with subsidies, the 'market' argues that the motivation of households to take measures is lacking'. The third interviewee discusses this factor on the household level and argues that the responsibilities within the insulation project are clear.

Category C: Physical interdependencies

The interviewees argue that the impact on the house of installing the insulation depends on the type of house, although does not often have a large visual impact, hence the low score for C1 (physical embeddedness). Interviewee 2 scored D2 (disturbance of regular operation) with a high score. She argued that this is one of the main reasons for households to abstain from insulation, as they expect their house to become messy during the construction. Although this is often a result of ignorance on the work that will take place All interviewees agree on a low technological uncertainty for insulation (C3), insulation materials have been used for decades and no major advancements have taken place.

Category D: Behaviour

In this category, the scores between the interviewees differ the most. On factor D1 (awareness of actor), the interviewees agree that this is an important barrier. Interviewee 1 points out that people do not see the heat efflux their homes. Interviewee 3 illustrates this in the phrase that households are not aware that their home is 'as leaky as a sieve'. She also adds that knowledge is lacking on which steps should be taken to insulate the house. The frequency of opportunity (D2) is a topic where interviewees provide different points of view. Interviewee 2 and 3 point out that the market offers options continuously, 'you can call the contractor everyday'. However, households act on 'natural moments' such as combining the installation of insulation with other constructions in their home, or when they move (Interviewee 1). The change of day-to-day behaviour for households is limited. According to the interviewees some changes regarding ventilation can take place. Interviewee 2 scored this factor with a high score, due to the barrier households see in this aspect and wonder if they can still open their windows. Due to this ignorance on the actual impact, this barrier is perceived by households.

Scoring variance

Some barrier scores showed variance between interviewees as can be observed in figure 4.1. Table 4.1 shows a categorisation of the reasons for this difference in scoring. The interviewees are noted in brackets. All uncertainties in for this abatement option are low. Barrier A2, B1, B3 and D1 are categorised as 'similar arguments, different conclusion'.

Table 4.1 Insulation: Sources of uncertainty on barrier scores

Barriers	Source of uncertainty	Explanation
B4. Responsibility unclear	Different frame of reference	The factor is discussed on national level (1), difference in saying and acting (2), within a project (3)
C2. Disturbs regular operation	Perception of barrier	Households are ignorant on the real disturbance: duration and intensity) (2)
D2. Frequency of opportunity	Similar arguments, different conclusion	Natural moments (1,2,3), neighbourhood approaches / collective buying (2, 3), call anytime (3)
D3. Behaviour change	Perception of barrier	Households are ignorant on the impact of a new ventilation system on their day-to-day behaviour (2)

Missing barriers
One interviewee (2) mentioned the influence of the direct social environment as being an important and trustworthy source of information as well as a motivator. This aspect was also mentioned by interviewee 3 under factor D1 (outside of thinking scope of actor). The neighbour is seen as a truthful source of information and conversations on this topic in the social environment of the household stimulate to taking steps for insulation.

I interpret this missing factor as an intervention to reduce barriers, especially the relevant barrier for insulation that households are ignorant on the actual instalment of insulation and how it affects their day-to-day behaviour. The social environment can play an important role in informing households on this matter and motivate them to insulate their homes.

Links between barriers
The interviewees have named a variety of links between barriers. The largest denominator is the different reasons households see for postponing the insulation of their house. Taking the measure is not 'in their thinking scope' (D1), as well as the fact that many lack knowledge on the exact impact. Reasons for postponing are that money can only be spent one time (A1: investment costs) as well as the perception of hassle of the installation (C2: disturbance of regular operation). Next to this, households do not feel responsible for insulating their homes (B4: responsibility unclear). In collective purchasing actions, there is a link between the investment costs (A1) and the dependence on other actors (B1). A group of households in a neighbourhood has to buy insulation materials at the same moment to receive the discounted price. When a household takes a loan for the insulation investment, it depends on the bank for financing (link B1 (dependence on other actors with A3, financing investment)).

Barrier score stability over the past decade
In the last ten years the discussion on climate change gained more attention in mainstream media. This leads to an increase of the awareness (D1, outside thinking scope) of households on the relevance of this topic and potentially acting on it as an individual. It is however not yet default to insulate your house. Other categories such as costs and technological development did not develop noteworthy in recent years according to the interviewees.

Interventions to reduce barriers
In table 4.2, an inventory of the interventions mentioned by the interviewees is presented. These are placed (by the author) in the row(s) of the barrier they relate to. Most interventions have the aim of informing households, thus increasing both the awareness and knowledge on insulation of households (D1). However, these interventions are applied on a neighbourhood or sometimes city-level. The upscaling of some of the proposed interventions (e.g. door-to-door advice) is rather difficult due to the large number of effort needed. It is challenging to design scalable interventions to inform such a large number of households (B2) in a manner that links to their motivations and the diverse housing stock (B3).

Table 4.2 Insulation interventions inventory

Barrier	Interventions mentioned by interviewees	Score
A1. Investment costs	Collective purchasing actions lead to a reduction in investment costs	Medium
A2. Payback period	Real estate agents who can stimulate to insulate the home before selling it, instant return on investment for seller Subsidies can reduce the payback period	Medium
A3. Financing investment	Renovation stores and Energy Counters offer financing options Energy reduction loans	Medium
B1. Dependence actors	Renovation stores and Energy Counters ('Energieloketten') offer independent advice, help with permit applications and offer overviews of different insulation options, request quotations Energy Cafés offer independent information	Low

B2. Number actors	Adapting the information on insulation to the type of households in a neighbourhood according to data about their attitudes towards life (e.g. prefers to have certainty, financial motivations)	High
B3. Types actors	Adapting the information on insulation to the type of households in a neighbourhood according to data about their attitudes towards life (e.g. prefers to have certainty, financial motivations)	High
B.4 Responsibility division		Low
C1. Physical embeddedness		Low
C2. Disturbs operation		Low
C3. Technological uncertainty		Low
D1. Awareness of actor	Door-to-door approach to inform people Publishing articles on websites and in newspapers Sustainable awareness campaigns by the government Attention for climate change in mainstream media Collective purchasing actions in neighbourhoods Step-by-step guides to help households Pop-up shops to inform people with heat pictures of homes in a neighbourhood	High
D2. Frequency of opportunity	Subsidies can create urgency	Medium
D3. Behaviour change		Low
Other	The process of informing the tenants before and during the installation of insulation is essential for their evaluation of the disturbance of the measure.	

Methodological insights

From the interviews on insulation for households, the following insights regarding the barrier factors were gained:

Different scale levels used in category Multi actor complexity

- In category B (multi-actor complexity) different scale levels are used. In factor B1 (dependence on other actors) the interviewee was asked which parties were needed to perform the insulation of their house. This is thus the scale of one household. In factor B2 (number of actors), the interviewee has to think on another scale level: 'How many actors need to take action to implement the abatement option on a large scale?' As the geographical scope for this research is the Netherlands, this leads to the answer of millions while on the 'household level'. For factor B3 (types of actors) the diversity is high, as there is a large heterogeneity of households. For factor B4, the interviewees interpreted the question differently, concluding from their answers on different scales.

Perceived barriers

- For factor C2 (disturbs regular operation) and D3 (change in behaviour) an interesting observation was made. People often have the perception that the installation will cause quite some hassle. This is a subjective feeling thus cannot be judged with objective facts. Although the problem is, people do not know how long it will actually take to install insulation and if it causes mess. This *perceived* barrier which blocks the household from taking action is high. The lack of knowledge is thus most likely the source of the barrier. Interviewees claim that insulation of floor and walls takes approximately one or two days. If this is a 'high' disturbance depends on the opinion of the household, but objectively it is short in comparison to other abatement options. The reason that the barrier is relevant for the household, makes it relevant for the party who wants to stimulate households to insulate their houses.

4.3 Carbon Capture Storage

This section describes the information gathered in the interviews regarding the barriers that are blocking Carbon Capture Storage projects in the Netherlands from being realised. The defined scope is full-chain projects: capturing CO_2, transport through pipelines and storage (focus on offshore), in the Netherlands. Interviewee 6 discussed the Barendrecht case, which was an onshore project she researched elaborately. In appendix B the interview reports of the experts can be found. Uncertainties regarding the scoring will be discussed as well as methodological insights from this case.

Figure 4.2 shows the scores that were provided by the interviewees to rate the barriers. The high investment costs with the perspective of no or a long pay-back period make the financial barriers (category A) substantial for CCS-projects. The dependence on other actors (B1) is large with respect to subsidies and permits. The Netherlands also has limited locations (D2) for CCS-projects available due to the set focus of offshore storage. The story behind the other barriers will be further elaborated on in this section.

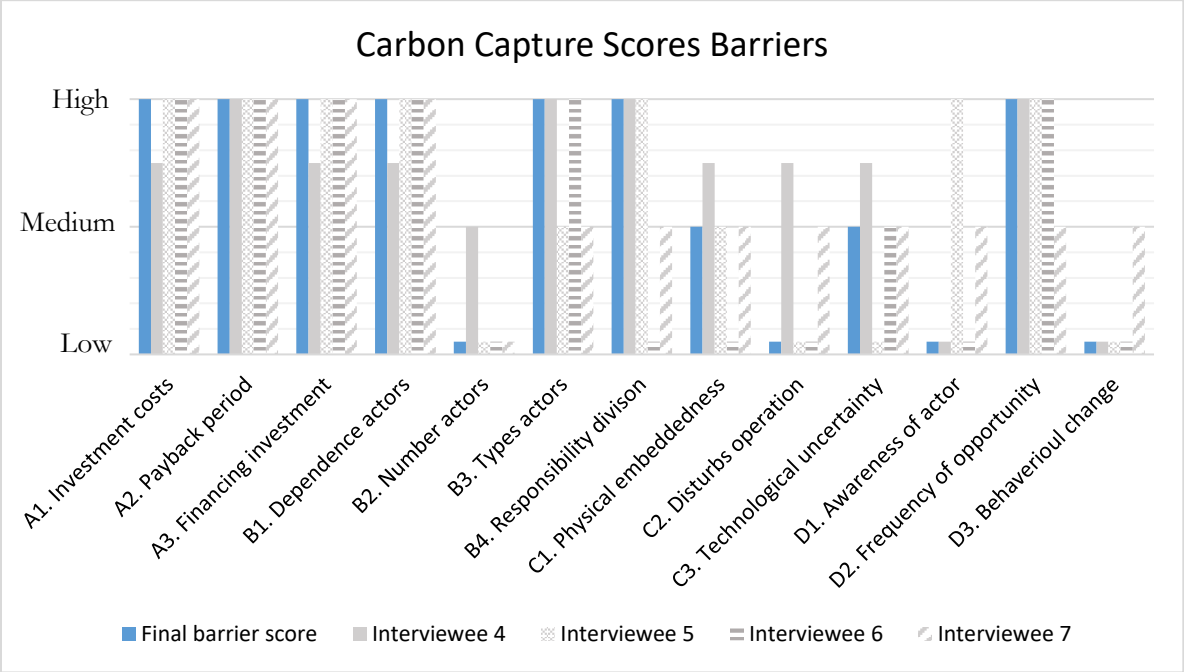

Figure 4.2 Carbon Capture Storage barrier scores

Barriers to Carbon Capture Storage (CCS)

Category A: Costs and Financing

The costs and financing of CCS-projects is a large barrier for starting projects. Interviewee 5 and 7 argue that the investment costs (A1) for a project are a few hundred million euros. Costs can be reduced when existing infrastructure can be used. All interviewees mention that the CO_2 -price is currently too low to build a business case for CCS. This leads to a long or no payback period for such projects (A2). It is highly difficult to finance projects, due to the lack of a (positive) business case (interviewee 4 and 5). Large add-on subsidies are needed to finance a project (A3). For the ROAD-project in Rotterdam (CCS offshore), (which was cancelled in September 2017), European and national subsidies were available.

Category B: Multi-actor Complexity

The interviewees agree on a high score for the dependence on other actors (B1), although the reasoning is different. Interviewee 4 argues that many actors should be involved in a project (industrial hubs, owner of the transport pipeline, government, supervisory party, owner of the storage, municipalities, local residents, research institutions). Interviewee 5 describes some complicating dependencies for CCS-projects, for instance the lack of several regulations, subsidies and a difficult permit procedure. Interviewee 6 adds a new insight into the influence of different parties, this depends on the cultural context. The number of actors (B2) is limited in CCS-projects in industrial clusters. The interviewees mostly named a diversity in interests (B3) among the stakeholders, interviewee 7 mentions: government, reaching the goals of the

Paris agreement including the existing competitive position of companies, industry: reaching the goals with lowest costs, society: safety first, no money to the fossil industry but also making the energy transition with low cost, NGOs often adhere to the polluter pays principle. The high score was chosen over the medium score for this factor as some of the interests of the stakeholders are opposing .
The division of responsibility (B4) is viewed differently amongst the interviewees. Interviewee 4 and 5 mention e.g. indistinctness on the responsibility for safety of the storage location of the CCS and the duration of this responsibility. Interviewee 4 also mentions that it is unclear if the government or business should take the lead in CCS-projects. Interviewee 7 says that the industry is waiting for government to create subsidy schemes and create boundary conditions. However, this collides with the 'polluter pays' principle that some parties adhere to.

Category C: Physical interdependencies
The changes to the environment (C1) are limited for CCS. The interviewees mention that often existing infrastructure can be used, and any visual impacts are less notable in industrial areas. Some adaptions to the factory are needed to add CO_2 capturing (interviewee 5). The installation of the CCS-chain does not have significant impact on the regular production process (C2) according to all interviewees. Three interviewees agree on the fact that the technological uncertainty (C3) is proven for the different parts of the CCS-chain, however, no full-chain project has been realised in Europe yet. Hence, the medium score for this barrier.

Category D: Behaviour
The interviewees agree on the awareness (D1) of industrial parties of the existence of CCS. Two interviewees mention the difference between awareness and knowledge of the actor in two examples: knowledge of industries on how to implement CCS (interviewee 7) and knowledge of Dutch citizens on CCS (interviewee 6). The frequency of opportunity (D2) for CCS is rare as interviewee 4 argues that the focus will be on industrial clusters, which are limited in the Netherlands. Interviewee 5 adds that CCS-projects can only be borne by large emitters due to the long responsibilities and high costs. The interviewees agree on the limited behavioural change (D3) resulting from a CCS project. Interviewee 6 adds a different perspective for this factor, as she argues that CCS is meant as a transition technology in the energy transition. The necessary lifestyle changes for citizens resulting from this transition, can be more smoothly instead of headlong when CCS is used.

Scoring variance
Some barrier scores showed variance between interviewees as can be observed in figure 4.2. Table 4.3 shows a categorisation of the reasons for this difference in scoring. The interviewees are noted in brackets. Barriers B2, B3, C2, C3 and D3 are categorised as 'similar arguments, different conclusion.

Table 4.3 Carbon Capture Storage: Sources of uncertainty on barrier scores

Barrier	Source of uncertainty	Explanation
B4. Responsibility division	Different frame of reference	Project level (6) compared to more general level of a Dutch CCS-project (4,5,7)
C1. Physical embeddedness	Different frame of reference	Project level (6) where reuse of infrastructure was possible compared to the more general impact of CCS-projects on the environment (4,5,7)
D1. Awareness of actor	Different frame of reference	Reasoning from large industry (4,5,7) or also local residents (6). Discussion of the difference between knowledge and awareness (6,7)
D2. Frequency of opportunity	Different understanding of barrier	Permit procedure can be started every day (7), only few parties can bear CCS-projects (5), limited number of industrial clusters (4).

Missing barriers
Three interviewees mention a missing factor related to public acceptance such as 'societal perception and acceptance' or 'public support'. Two interviewees claim that certainty on policy on the long-term is essential for businesses to take in investment decisions. Interviewee 7 mentioned the missing factor of indistinctness on the coordination in projects where different parties are responsible for different elements of the chain. It is unclear which party should take the lead to align all parties.

I interpret this last factor to be part of B4 (responsibility unclear), as it appears the responsibility for the leading role is not natural in this case, neither that it is (yet) assigned. The interviewee also posed this coordination problem while discussing factor B1 (dependence on other actors). This is explicable as the interviewee felt that there was considerable cohesion between the barriers and had difficulty separating these.

Links between barriers
Interviewees mentioned different types of links. Many relate to the important barriers in the costs and financing category. The roles and responsibilities (B4) should be clearly defined to provide certainty to the business to make investment decisions on CCS. Next to this there are important dependencies (B1) with regard to subsidies (C3, financing of investments) on national and international governments. Reusing existing infrastructure (C1) can lead to a reduction in investment costs (A1).

Barrier score stability over the past decade
Not much changed for CCS regarding the costs and financing (category A). The CO_2-price is still too low to build a viable business case. The multi-actor complexity (category B) increased compared to ten years ago, transport *networks* are needed instead of pipelines as the focus is currently on industrial clusters instead of single industrial parties. Interviewee 4 adds that this new focus might increase the difficulty on technical aspects (C) as well, as the scale of the projects increases in networks. The current focus on industrial clusters and offshore storage may reduce the opposition from society in comparison to onshore projects (B3). CCS was given a prominent place in the recent government agreement in the Netherlands, which shows political support (2017) .

Interventions to reduce barriers
In table 4.4 the interventions mentioned by the interviewees are presented. These are placed (by the author) in the row(s) of the barrier they relate to. The interventions mentioned can often be connected to several of the high barriers (costs and financing (A) and multi-actor complexity (B)) for CCS projects to be realised. The frequency of opportunity (D2) is the only barrier were no actual intervention is mentioned. The increased urgency may be beneficial to realise projects, although due to past experiences the number of opportunities was also limited more, only offshore storage, the current focus on industrial hubs. A minimum CO_2-price (A2) would be effective to strengthen the business case for CCS. As this is part of the government agreement of 2017, it seems to have political support.

Table 4.4 Carbon Capture Storage: Inventory of interventions

Factor	Interventions mentioned by interviewees	Barrier
A1. Investment costs	Technological research can result in cost reduction	High
A2. Payback period	Minimum CO_2-price to strengthen business case	High
A3. Financing investment	EU-funding for demonstration projects Developing regulations on the subsidy scheme	High
B1. Dependence actors	Acceleration of the permit procedure Development of a long-term vision from the government	High
B2. Number actors		Low
B3. Types actors	EU-funding for technical and social scientific research Compensation scheme for local residents in case of CCS onshore	High
B4. Responsibility division	Developing regulations on responsibilities of different parties on the risks of CO_2 storage Development of a long-term CCS- vision from the government	High
C1. Physical embeddedness		Medium

C2. Disturbs operation		Low
C3. Technological uncertainty	EU-funding for technical and social scientific research EU-funding for demonstration projects Knowledge exchange with different countries	Medium
D1. Awareness of actor		Low
D2. Frequency of opportunity	The Climate Agreement of Paris and the lawsuit of Urgenda create an urgency to take climate action	High
D3. Behaviour change		Low

Methodological insights

Lack of awareness or knowledge?

- Two interviewees argued that for factor D1, awareness of actor, two aspects should be distinguished: the level of *awareness* and the level of *knowledge*. For industrial parties, knowledge means the company knows if the technology is applicable in its company and it knows (roughly) the outline of the implementation process. For local residents, the level of knowledge can be tested on asking questions on facts related to CCS. Awareness is thus a low level on the 'knowledge scale'.

4.4 Biofuels

This section describes the information gathered in the interviews regarding the barriers that are blocking the adaptation of biofuels in the Netherlands. The defined scope is the use of high blends of biofuels by private car owners in the Netherlands. For most interviews it was aimed to focus more on the adoption by private car owners. Interviewee 8 discussed a larger part of the biofuel production chain. In appendix B.3 the interview reports of the experts can be found. Uncertainties regarding the scoring as well as methodological insights will be discussed.

Figure 4.3 shows the scores provided by the interviewees to rate the barriers. The fuel costs of biofuels are higher than fossil fuels which is a barrier for car owners to switch to using biofuels. The number of actors (B2) which would have to make a change is large, as well as the diversity of this group (B3) and of their cars. Only gasoline cars need to be adapted to use high blends of biofuels (E85), this is not necessary for the use of biodiesel or bio-CNG. Currently not many Dutch citizens are aware (D1) of the option of driving on biofuels and the fact that it is blended in small proportions in their current fuel. The story behind the other factors will be further elaborated on the remainder of this section.

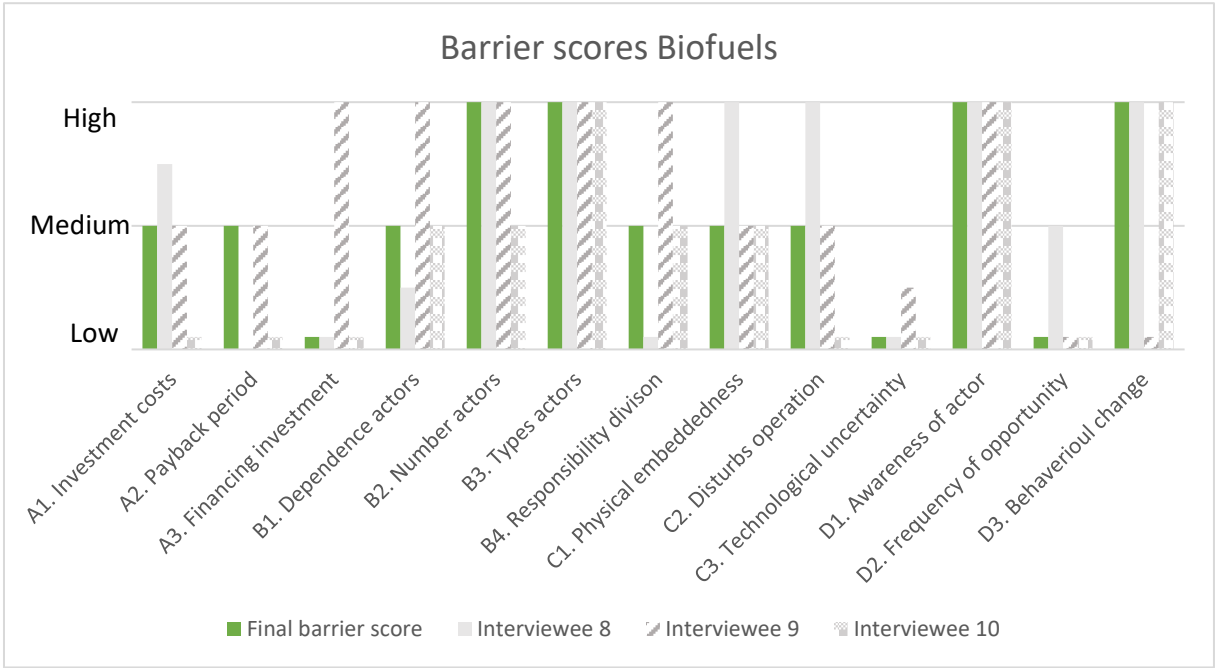

Figure 4.3 Biofuels barrier scores

**No score for A2 was provided by interviewee 8.*

Barriers to biofuels

Category A: Costs and Financing

The scores for the costs and financing category are diverse in this category. This shows that it is difficult to reflect the cost-structure of changing to biofuels in the Y-factor. The cost structure of a biofuel car is low/no investment costs and high operational costs (in comparison to fossil fuel cars). Only gasoline cars need a small investment for adapting their engine. Biofuel is currently more expensive than fossil fuel. Therefore, the factors A1 (investment costs) and A2 (payback period) are not suitable to describe the financial barriers of changing to biofuels. Two interviewees explained that the cars are often compared with respect to their total cost of ownership (TCO). This is a multiplication of *investment costs for adapting vehicle / new vehicle * fuel costs * average distance covered per year.*

Category B: Multi-actor Complexity

For the dependence of other actors (B1), the interviewees discuss that the parties in the production chain should work together closely to scale up. Interviewee 9 adds that it is yet unknown how the costs and benefits will be divided over the chain. In the current system (where biofuel is blended in low percentages with fossil fuels) the costs are borne by the consumers. The number of actors (B2) is high. Interviewee 10 argues that this number does depend on the 'location' in the biofuel chain where policy is aimed at. When

an obligation to blend biofuels is aimed at the fuel producers, the number of actors is more limited. This is possible for biodiesel (HVO) and bio-CNG ('GroenGas') as these can be used by consumers without adapting cars. The diversity of actors (B3) is a particular problem for biofuels. There is a difference of opinion between countries of the European Union (which mostly develops regulation on biofuels). Interviewee 9 provides another perspective, as he expects the consumer to set requirements to the origin of the biofuel. This would ask for a different organisation of the sector, which is now organised to produce bulk products. The responsibility (B4) to increase the amount of almost pure biofuels used is not yet assigned to one party. Currently the fuel producers have obligations from the European Union to reach certain targets on CO_2-intensity of their sales.

Category C: Physical interdependencies

The discussed focus/scale level in the biofuel chain is a relevant topic in this category, as the differences between the scales are rather large. At the end of the chain, there is a difference between cars, gasoline cars need to adapt their motor (C1, physical embeddedness), while CNG and diesel cars don't (Interviewee 9). Fuel stations have to be adapted as well to use gasoline with a high percentage of biofuels (Interviewee 10). Two interviewees mention the availability of biomass or waste streams for biofuel production. The disturbance of the regular operation (C2) is limited, only owners which want to use high-biofuel blends have to adapt their car (interviewee 9 and 10). All interviewees agree on the fact that the biofuel technology is proven which leads to a low technological uncertainty (C3).

Category D: Behaviour

Many of the car users are not aware (D1) of the blending in of biofuels which is currently taking place according to interviewee 9 and 10. For some fuels (diesel and CNG) the consumer can pick the 'green' option each time he/she refuels (interviewee 9 and 10) (D2, frequency of opportunity). The car owner has to pick a different pump at the gas station when he/she refuels its car (D3). It may require extra effort to keep car owners from switching to the cheaper fossil fuel.

Scoring variance

Some barrier scores showed variance between interviewees as can be observed in figure 4.3. Table 4.5 shows a categorisation of the reasons for this difference in scoring. The interviewees are noted in brackets. Barrier B2 and C1 are categorised as 'similar arguments, different conclusion.

Table 4.5 Biofuels: Sources of uncertainty on barrier scores

Barrier	Source of uncertainty	Explanation
A1. Investment costs **A2. Payback period**	Ill-fit with Y-factor categorisation	The cost structure of changing to biofuels is low to no investment costs and constantly higher fuel costs, which is difficult to reflect in the Y-factor categories (8,10). Investment in the production chain are significant (8,9)
A3. Financing investment	Different frame of reference	Small investment to change car (8, 10), support from government is needed for market rollout (9)
B1. Dependence actors	Different frame of reference	Different parties in the production chain are mentioned (all). Support from government is essential (9). Difference for types of cars, gasoline cars depend on garages to adapt their motors (10).
B4. Responsibility division	Different frame of reference	Division of costs and benefits in the production chain is unclear when there is a large upscale of biofuels (9). Households see the extra costs of biofuels as a barrier, most will only pay these when being obliged (10). Currently fuel producers have the obligation to blend in biofuels (8,10).
C2. Disturbs operation	Different frame of reference	A discussion of the full chain (8) compared to a discussion of the end of the chain, consumers (9, 10).
D2. Frequency of opportunity	Different frame of reference	Each time you visit the gas station (9,10), when you buy a new car (8)

D3. Behavioural change	Similar arguments, different conclusion	Choosing another pump at the fuel station is interpreted differently as a small or large change. Effort is needed to keep people to stick to picking the more expensive biofuel.

Missing barriers

Two interviewees mentioned the 'public perception' as a lacking barrier for the adoption of biofuels. When biofuels became known by the public, the requirements for sustainable biofuels resources were not known yet. This resulted in a bad image for biofuels which is still in the minds of the consumers (Interviewee 10). At the moment, new standards have been set also with regard to the issue of indirect land use change (ILUC) and sustainability requirements for biofuels.

The 'strong interests of incumbents' is mentioned, as these prefer to stick with the current system and maintain their position in the market. This also relates to the concept of 'path dependency', as the current incumbents most likely invested in the current physical system.

In my view the 'interests of incumbents' is a barrier which is part of factor B3 (types of actors) as these incumbents most likely are a strong actor in the transition in the transport sector. These actors can pose unexpected barriers, thus it is interesting to keep them in mind. Path dependency relates to factor C1, physical embeddedness, to what extent are extra changes to the environment needed? The current system is also part of this environment.

Links between barriers

Two interviewees mentioned the link between the frequency of opportunity (D2) and the fuel prices (A) of biofuels (higher than fossil fuels). For some fuel types (diesel and CNG) the consumer must choose the more expensive green option time after time at the fuel station. Interviewee 10 illustrates this in the example of plug-in hybrids, where car owners choose diesel over electric driving more often than expected. Interviewee 9 adds two other links that both relate to the position of the government. A strong and long-term position on biofuels from the government is needed to provide certainty to investors in the biofuel chain (B1, dependence on other actors) as well as subsidy on biofuels (A3, financing of investment) to provide competitive market prices.

Barrier score stability over the past decade

In the previous ten years, research led to requirements for sustainable production of biofuels. Interviewee 9 argues that more research is however needed. The production chain of biofuels was realised in the previous ten to fifteen years. The costs of biofuels did not change much. The political environment changed in the last years, which leads to uncertainty for investors in the biofuel chain. The urgency to act on climate change increased due to the Paris agreement.

Interventions to reduce barriers

All interviewees mentioned a different taxation system for fuels, based on CO_2-intensity of the fuel to take away the price disadvantage of biofuels. This intervention connects with category A (Costs and Financing). Long-term policy is necessary to provide enough certainty for companies to invest in upscaling the biofuel production (B1). As the Dutch car fleet and car owners are diverse, a mixed program must be set up to offer options for all car owners (B2, B3). Awareness campaigns is an option to inform people on biofuels (D1), as many do not know they are currently also driving on a fuel blend which includes biofuels. Many of the interventions connect to the main barriers for the adoption of biofuels.

It will be challenging to convince such a diverse group, especially due to the complexity of the topic. Also convincing these people of the developments regarding the origin of the biofuels will most probably be difficult to communicate. In my opinion, the garage owners can play an important role in this as well, through informing their clients of the option of biofuels. Next to this, interviewee 9 addressed that the government currently focusses on electrical vehicles, although the uptake for these vehicles is rather slow due to the high price (20,000 EVs of 8.2 million cars in total). From 2030 only EV's will be sold, but in the period it before, the CO_2-intensity of fuel should be lowered. Biofuel can be a relevant option for reducing this CO_2-intensity. Interviewee 10 mentions that the transport sectors inland shipping, heavy road transport and aviation are often discussed in relation to biofuels. The barriers would have a different shape as the number of actors and actor types is different from this research as well as the investment decisions made by these parties. Table 4.6 shows all interventions which were mentioned by the interviewees.

Table 4.6 Biofuels: Inventory of interventions

Barrier	Interventions mentioned by interviewees	Score
A1. Investment costs		Medium
A2. Payback period	Taxation of fuels related to their CO_2-intensity or through providing a financial reward for the reduced CO_2 emission to make the price more competitive to fossil fuels Subsidies to provide equal prices for biofuels and fossil fuels	Medium
A3. Financing investment	Strong long-term policy from the government is needed to provide parties certainty for investments in biofuel factories, e.g. shaped as an obligation to use biofuels	Low
B1. Dependence actors	Strong long-term policy from the government is needed to provide parties certainty for investments in biofuel factories, e.g. shaped as an obligation to use biofuels Setting up a system of 'Guarantee of Origin' for Green Gas (Bio-CNG) to provide certainty about the availability Offer a conversion kit for gasoline cars to car garages to make it possible to drive on E85-gasoline Gasoline stations must install a new pump and storage space for gasoline (E85) Expanding the regulation from EU with regard to biofuels One contact point for government from the biofuel sector for long-term consultation (platform) Stimulating cooperation and knowledge exchange in biofuel sector (platform)	Medium
B2. Number actors	Setting up a mixed program to appeal to all car owners (diesel, gasoline, CNG) and thus proved customised advice Setting up awareness campaigns focussed on behavioural change of consumers through developing a communication strategy	High
B3. Types actors	Setting up a mixed program to appeal to all car owners (diesel, gasoline, CNG) and thus proved customised advice Stimulating cooperation and knowledge exchange in biofuel sector (platform)	High
B4. Responsibility division		Medium
C1. Physical embeddedness		Medium
C2. Disturbs operation		Medium
C3. Technological uncertainty	Stimulating cooperation and knowledge exchange in biofuel sector (platform)	Low
D1. Awareness of actor	Setting up awareness campaigns focussed on behavioural change of consumers through developing a communication strategy	High
D2. Frequency of opportunity	Stimulating consumers to stick to green choices, (diesel and bio-diesel are interchangeable as well as bio-CNG and CNG).	Low
D3. Behaviour change	Stimulating consumers to stick to green choices, (diesel and bio-diesel are interchangeable as well as bio-CNG and CNG).	High

Methodological insights

Ill-fit with barriers in category Costs and Financing

- Two interviewees indicated that the factors category A (Costs and Financing) do not fit the normal cost structure of investing in the change to driving on biofuels. This led to a large variation in scores in this category. The cost structure of a biofuel car is low/now investment costs and high operational costs (in comparison to fossil fuel cars). Therefore, the concept of 'investment costs' (A1) and 'payback period' (A2) are not suitable to describe the financial barrier of changing to biofuels. Vehicles with different fuels are compared through evaluating the Total Cost of Ownership. This is a multiplication of *investment costs for adapting vehicle / new vehicle * fuel costs * average distance covered per year.*

Difficulty in scoping

- The biofuel case was the most difficult case to fit into the Y-factor scheme. The case was scoped to the geographical scope of the Netherlands, where questions were asked from the point of view of the households: What barriers do households see for starting to drive on biofuels? All interviewees indicated that it was difficult to solely reason from the household, as for a large adoption of biofuels changes must take place in the production chain (resources, processing, distribution). This chain is however not confined to the Netherlands. Rather different barrier explanations and scores are given when the interviewees take into account the full chain. The relevant barriers can also be quite different within the chain, a change of crops for a farmer is quite a change of behaviour.

4.5 Geothermal energy

This section describes the information gathered in the interviews regarding the barriers that horticulturists, who would like to become a geothermal operator, see for starting a project. The defined scope is horticulturalists in the Netherlands. Interviewee 12 also discussed barriers for implementing geothermal energy in the built environment but focussed the scoring on the horticultural environment. In appendix B.4 the interview reports of the experts can be found.

Figure 4.4 shows the scores provided by the interviewees to rate the barriers. The high investment costs together with the long pay-back period make the financial barriers (category A) high for geothermal projects. The dependence on other actors (B1) is large with respect to subsidies and permits as well as the fact that horticulturists often work in a consortium to finance the construction of a geothermal source. The largest source of uncertainty comes from geological uncertainty (C3). What is found in the underground determines the output of the geothermal source.

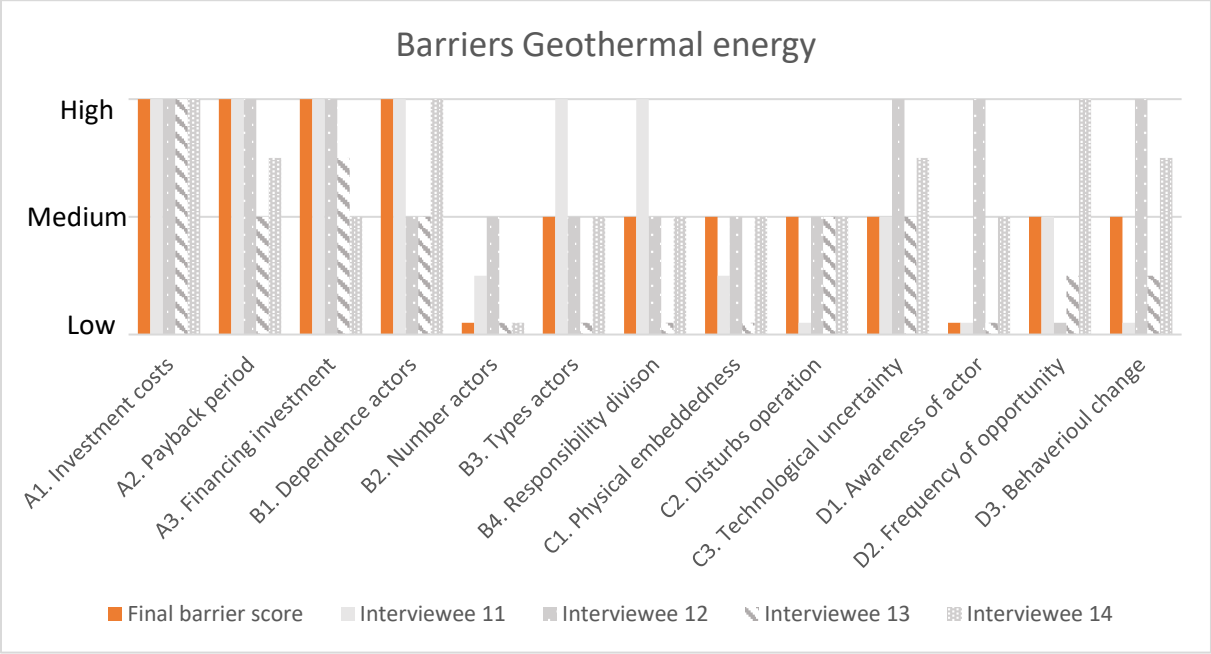

Figure 4.4 Geothermal energy barrier scores

Barriers to geothermal energy

Category A: Costs and Financing

The main barriers for horticulturists to construct a geothermal energy source are of financial nature (category A). The investment costs (A1) for a geothermal source are several millions of euros (interviewee 13 and 14). The payback period (A2) of geothermal energy is between ten and fifteen years. According to all interviewees, subsidy (SDE+) is needed to make a viable business case (A3, financing of investment). All interviewees argue that the largest risk factors banks see for geothermal projects are geological risks (what quantity of production will the source deliver). Parties who want to become geothermal operators need to finance a large part of the investment with equity, therefore horticulturists have been conducting projects lately in joint-ventures (Interviewee 14).

Category B: Multi-actor Complexity

Multi-actor complexity is a relevant barrier source for geothermal energy projects. Interviewees mention a variety of actors and the dependence on this party in the project (B1). Banks (loans), government (granting party and licensing authority), local residents, municipality (licensing authority), consultancy firms (technological research of underground), SodM (supervisory authority, 'Staatstoezicht op de Mijnen'), and, if present, an operator of the heat network. All interviewees argue that the number of actors involved in a project is limited (B2). When the geothermal source is meant to heat residential houses, the number of actors even increases. The diversity of actors (B3) leads to interesting insights. Interviewee 14 mentions that some of the actors involved have a duality of interests within their organisation. For example the Ministry of

Economic affairs and Climate has the interest of realising many sustainable energy sources while at the same time being the permitting authority. The division of roles and responsibilities (B4) led to a variety of answers from the interviewees. Two argued that the roles within projects are clear (12, 13). Interviewee 12 also mentioned that it is not yet clear who will take the responsibility for upscaling the number of geothermal energy projects. Next to this, interviewee 11 argues that the role of SodM is not completely clear as this party is a supervisory authority but has to provide advice to small projects regularly. This topic was addressed in a formal letter to the Ministry of Economic Affairs (Staatstoezicht op de Mijnen, 2017)

Category C: Physical interdependencies

Factor C1, physical embeddedness, is according to all interviewees limited. Most interviewees stress the limited visual Impact of a geothermal source, a small building which houses a heat exchanger, does not stand out in a horticultural environment. All interviewees argue that the disturbance of the project is limited (C2), local residents may be disturbed by nuisance. Interviewee 13 adds that the construction of the well also can lead to some logistical challenges on the terrain itself. The most important technological uncertainty (C3) is the geological uncertainty. The quantity of the output of the source depends on what is found in the underground. Interviewee 14 mentions some uncertainty on the break-down time of different parts.

Category D: Behaviour

Horticulturists are aware of the option of heating their greenhouses with geothermal energy (interviewee 11, 13, 14). A geological research is needed to see if the technology is applicable at their site (interviewee 14). The frequency of opportunity is interpreted differently by the interviewees. Interviewee 12 and 14 mention aspects related to timing, such as the replacement of a heating source or the availability of equity. Interviewee 11 and 13 focus on the 'location-dependency' for geothermal energy as not all provinces have a suitable underground/geology. The change of behaviour (D3) for a starting geothermal operator is according to most interviews limited. Interviewee 14 however argues that the change is larger than expected beforehand.

Dissimilarity in scoring

Some barrier scores showed variance between interviewees as can be observed in figure 4.4. Table 4.6 shows a categorisation of the reasons for this difference in scoring. The interviewees are noted in brackets. Uncertainties of B1, B2 and C1 are categorised as 'similar arguments different conclusion.

Table 4.6 Geothermal Energy: Sources of uncertainty on barrier scores

Barrier	Source of uncertainty	Explanation
A2. Payback period	Ill-fit with Y-factor categorisation	Different pay back periods mentioned, between 5 and 12 years (13), between 10 and 15 years (14). Medium Y-factor category is between 5 and 12 years.
A3. Financing investment	Different frame of reference	Horticulturists that want to build a geothermal energy source are dependent on loans of banks (11, 12, 13). One interviewee adds the companies which can finance projects independently from income of existing geothermal sources (14)
B3. Types actors	Different frame of reference	All named a similar group of actors, however difference in focus in the answers. Diversity of interest within the ministry (14), focus on local residents which can be diverse and have different opinions towards using heat networks (12)
B4. Responsibility division	Different frame of reference	Upscaling of geothermal energy in the Netherlands (12). Clear within a project (13). Relationship of supervising authority, permitting authority and initiator geothermal well (11, 14)
C3. Technological uncertainty	Different frame of reference	Geological uncertainty (11, 12). Not fully mature sector (11, 13). Difference in break-down time of parts (14)

D1. Awareness of actor	Different frame of reference	Horticulturists are aware of the option of geothermal energy (11, 13, 14), but do not know if it is viable for their terrain (14). A limited number of municipalities is aware of geothermal energy (12)
D2. Frequency of opportunity	Different understanding of barrier	Natural moment, ending of gas contract (12). Sufficient savings are needed for investment, does not happen often (14). Dependency of location for the possibility of a source (11, 13). Permit procedure can be started anytime (13)
D3. Behaviour change	Different frame of reference	Few changes for horticulturists who become geothermal operators, larger change for households when connected to heat network (12). Few changes (11, 13). More changes than expected (14)

Missing barriers

Two interviewees (11, 14) mentioned the missing barrier 'societal acceptance' and 'political or public support'. Interviewee 11 poses the question if a local geothermal energy project become the stake of a national debate on geothermal energy or will it only get local or regional attention? Interviewee 14 observes: 'Most of the public in the Netherlands has never heard about geothermal energy. This means they have no opinion. It does not show that they are in favour or against geothermal energy. Influencing the opinion may be easy as there is no 'reference knowledge'.' She also addresses the missing barrier of the difference in seismic risk for every region.

In my view, the presence of seismic risk leads to a reduced frequency of opportunity (D2) in the Netherlands, as it is not possible in some regions to develop a geothermal source due to public acceptance issues which may arise or the risk that is estimated to be too high by the licensing authorities.

Links between barriers

The 'source barrier' for geothermal energy is the geological uncertainty, by some interviewees named while discussing C3 (technological uncertainty), others mentioned this aspect in the discussion on D2 (frequency of opportunity). The conditions of the underground determine the design and the production of the well. These determine the payback period (A2) and the investment costs (A3). A proper construction of the well is also important for the total investment during the lifespan of the well. Too little investment in the construction phase can lead to higher operational costs in the operational phase.

The geological uncertainty is also the most important risk factor for a bank when deciding about the loan conditions. Next to this, banks also find some uncertainty in the current regulations for permits (B1). These links are visualised in figure 4.5.

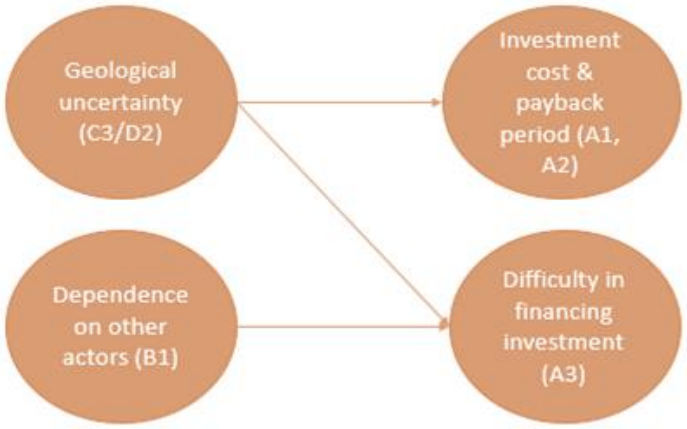

Figure 4.5: Geothermal energy: Links between barriers

Barrier score stability over the past decade

In the last ten years, the geothermal energy sector has grown in the Netherlands. Due to this experience, the technological uncertainty (C3) has become a bit lower (interviewee 12 and 14). However, geological uncertainty is still the largest source of uncertainty for geothermal energy projects. The political support for this type of heat source has grown as well as the urgency to act due to the Climate Agreement of Paris (interviewee 11). The investment costs and payback period (A1, A2) have increased due to more diligent drilling procedures (interviewee 14). SDE+ subsidy was started to make it possible for geothermal projects to have viable business cases (interviewee 13 and 14). Currently no sources aimed at heating in residential areas have been realised (interviewee 12).

Interventions to reduce the barriers

In table 4.7 the interventions that were mentioned by the interviewees are shown. Many suggested or already implemented interventions can be related to the barriers with a high score in the Costs and Financing category (A) and in the multi-actor complexity category (B).

Table 4.7 Geothermal Energy: Inventory of interventions

Barrier	Interventions mentioned by interviewees	Score
A1. Investment costs	SDE+-subsidy and guarantee fund ('garantiefonds' which insures the risk of unsuccessful drilling) provide certainty for the investment for geothermal operators	High
A2. Payback period	SDE+-subsidy and guarantee fund ('garantiefonds' which insures the risk of unsuccessful drilling) provide certainty for the investment for geothermal operators	High
A3. Financing investment	Projects with a high-quality execution can serve as showcases to increase trust of banks and public Through knowledge exchange innovation can take place to reduce project costs, gain more stable production of the wells and increase safety of projects. Reducing the risk makes it easier to finance projects	High
B1. Dependence actors	Clarification of the responsibilities of parties involved, adequate regulation, policy and supervision should be developed for the sector Adapting the permit procedure to shorten the procedure Projects with a high-quality execution can serve as showcases to increase trust of banks and public Research and experience can increase the level of professionalism of involved parties Informative meetings aimed at local residents, 24/7 telephone number for questions, informative website on geothermal energy, newsletters In urban areas extra budget should be spent on providing informing to local residents, installing 'geofoons' to register vibrations and making architectonic reviews of the condition of houses and buildings before drilling	Medium
B2. Number actors		Low
B3. Types actors	Research and experience can increase the level of professionalism of involved parties	Medium
B4. Responsibility division	Supply and demand should be matched to scale up geothermal energy. The government can be an organising party on this topic Clarification of the responsibilities of parties involved, adequate regulation, policy and supervision should be developed for the sector Research and experience can increase the level of professionalism of involved parties	Medium
C1. Physical embeddedness		Medium
C2. Disturbs operation	Placing a container to reduce noise pollution	Medium
C3. Technological uncertainty	Research should be performed on risks, how to manage these risks and the costs of managing these, precautionary measures to keep the well function properly Gaining more experience in non-urban areas to prevent public resistance Through knowledge exchange innovation can take place to reduce project costs, gain more stable production of the wells	Medium

	and increase safety of projects. Reducing the risk makes it easier to finance projects	
D1. Awareness of actor	Informative meetings aimed at local residents, 24/7 telephone number for questions, informative website on geothermal energy, newsletters	Low
D2. Frequency of opportunity		Medium
D3. Behaviour change		Medium

Most interventions that were mentioned by the interviewees relate to increasing the knowledge exchange between parties in the sector. This should reduce the technological uncertainty (C3), provide more insight into possible risks and how to control these and should reduce the development costs of new wells (A1, A2). The adaptation of regulation to make it more suitable for the sector (B1 and B4) is important, as this will take away a risk for projects (this topic is currently addressed).

I agree that adequate regulation is necessary to increase the number of geothermal projects in the Netherlands and should be adapted on the short term to provide certainty for initiators. Interviewee 12 addressed that it will be challenging to use more geothermal energy in the built environment as heat networks have to be built. Operators of these networks have to be sure that households will connect to this network. This challenge, together with increasing the knowledge exchange on diligent execution of projects is necessary to reduce the level of uncertainty on the output of the geothermal energy sources. Interviewee 14 also points out a relevant risk, in my opinion, a large part of the public is not yet aware of geothermal energy. It is important to keep this in mind when introducing more geothermal energy sources in the built environment and make a proper communication strategy for geothermal energy as well as proper stakeholder involvement processes.

Methodological insights

The discussion of 'geothermal energy' by using the Y-factor led to several methodological observations:

Relevance of scoping

- The scope is a relevant topic for geothermal energy. Interviewee 12 discussed extra challenges when implementing geothermal energy in the built environment instead of on a horticultural site. The investment costs are increased (A1), as a heat network needs to be built. The investment may become more risky for the network operator as a larger number of actors (citizens) have to be connected to use the produced heat (A3, B2). The actors in the built environment are also more diverse on the topic of changing to a different heat source in comparison to horticulturists (B3). The disturbance of the regular operation will be larger due to the construction of the heat network (C2). The awareness of actors (citizens) of the impact of connecting to a heat network are generally low (D1). A different scoping of this case would thus lead to a rather different scoring.

4.6 Comparison between abatement options

In this section, an analysis combining the four abatement options is presented for additional insight on the understanding of barriers to CO_2 abatement.

4.6.1 Comparison of narratives abatement options

This section presents the conclusions that can be drawn from comparing the abatement options and their barrier scores.

Households as initiators

The four investigated abatement options can be divided in two groups. First, insulation and biofuels where households are the initiators to insulate their house or change fuel for their car. These choices can be made quite independently of other actors (assuming biofuels are available at gas stations). The biggest challenge is to inform and convince this heterogeneous group (with respect to income, norms and beliefs, houses/cars). This results from the high barrier scores on B2 (number of actors), B3 (types of actors) and D1 (awareness of actors). Investment costs (A1) is a relevant topic as well for both options. This shows in the recurring higher price for biofuels, the car owners should repeatedly choose the green, more expensive, option. For insulation this translates into opportunity costs: Either choosing for a long-term investment that is profitable in a few years or spending the money on pleasure on the short term (e.g. a holiday).

Capital-intensive abatement options

Carbon Capture Storage and Geothermal Energy show similarity as both abatement options have an impact on the subsurface and therewith location is a relevant topic. What is found on the location, determines the capacity of the source. For CCS, a project can only be executed on a location where at least one large CO_2-emitter is present and a storage location (e.g. an empty gas field) is available in a radius of several kilometres of this emitter. For both abatement options the location influences the investment costs to a large extent. The transport infrastructure for heat and CO_2 are a substantial part of the investment costs. Both abatement options have high scores on the three barriers in the category costs and financing and a high score on the dependency of other actors. To start a project with these technologies, a number of permits from various parties is needed. The background story is essential to understand the differences in high scores for both technologies. The investment costs of CCS projects are more than ten times higher than geothermal projects (although take into account that the project sizes are different) (appendix B.2, B.4). The pay-back periods also show a large difference. A geothermal energy can be profitable (with subsidy) after ten to fifteen years. However, a CCS-project does not yet have a business case under the current CO_2-price and therefore does not have a payback period. This partly explains why currently no CCS-projects have been realised in the Netherlands, while the number of geothermal energy projects has been rising over the past years. The main challenge for these capital-intensive abatement options is to reduce uncertainty on the investment that results from technological aspects and regulation.

4.6.2 Sources of uncertainty

In the analysis of the abatement options, variance in scoring and supporting stories were observed. Table 4.8 shows a summary of the sources of uncertainties for the different abatement options. The table shows quite a large number of uncertain barriers due to the strict rules on assigning uncertainties. Already one interviewee deviating from the most mentioned barrier height (e.g. low, low, medium) the uncertainty classifies the uncertainty as low. Low uncertainty is marked in light grey. When two interviewees deviate from the most mentioned barrier height, it is classified as a high uncertainty. These are marked in dark grey. For a better overview in the table, the source of uncertainty 'similar arguments, different conclusion is marked as **.

Table 4.8 Comparison categorised uncertainties

Barrier	Insulation	Carbon Capture Storage	Biofuels	Geothermal energy
A1. Investment costs			Ill-fit with Y-factor categorisation	
A2. Payback period	**		Ill-fit with Y-factor categorisation	Ill-fit with Y-factor categorisation
A3. Financing investment			Different frame of reference	Different frame of reference
B1. Dependence actors	**		Different frame of reference	**
B2. Number actors		**	**	**
B3. Types actors	**	**		Different frame of reference
B4. Responsibility division	Different frame of reference	Different frame of reference	Different frame of reference	Different frame of reference
C1. Physical embeddedness		Different frame of reference	**	**
C2. Disturbs operation	Perception of barrier	**	Different frame of reference	**
C3. Technological uncertainty		**		Different frame of reference
D1. Awareness of actor	**	Different frame of reference		Different frame of reference
D2. Frequency of opportunity	Different frame of reference	Different understanding of barrier	Different frame of reference	Different understanding of barrier
D3. Behaviour change	Perception of barrier	**	**	Different frame of reference

Explanation uncertainty categories

Table 4.8 shows an overview of the different analysed sources of uncertainty for the difference in barrier scores provided by the interviewees.

Different frame of reference: From the answers of the interviewees, it can be concluded that they were not thinking of the same scope in illustrating the story behind the barrier score. In factor B4 (responsibility unclear) this can be evaluated on a project level as well as on a national level (who is responsible to scale up the adoption of an abatement option). This is the most common source of uncertainty.

Ill-fit with Y-factor categorisation: Some of the abatement options' characteristic barriers were difficult to fit in the Y-factor categories. An example is the car owner cost to change to biofuels. The fuel costs are constantly higher, but the investment costs are low.

Different understanding of barrier: Several interviewees asked for additional explanation of factor D2, frequency of opportunity. The stories on this factor differed nonetheless from 'a project can start everyday' to relating the start of a project more to 'natural moments' or certain boundary conditions which should be present.

Perception of barrier: An interesting difference in scoring was seen for the abatement option insulation. One interviewee indicated that the households perceive a large barrier in the factor 'disturbance of regular operation' (C2). The reason for this barrier is a lack of knowledge but is subjective as well. A perceived barrier is a similar barrier to an 'objectively' noticeable barrier.

Similar arguments, different conclusion: This uncertainty is not explicable from the story of the interviewees which are similar. The different conclusions might result from unspoken comparisons with other abatement options or recent experiences. It may also result from different types of expertise from the interviewees. Some interviewees also indicated that they possessed different level of knowledge on the different categories.

Reflection reducing uncertainty

The abatement options Carbon Capture Storage and Geothermal Energy show more uncertainty in their barriers scores, due to the fact these abatement options had four interviewees where the other abatement options had three experts interviewed. The choice on the number of interviewees was steered by time constraints and the requirement to interview experts from different backgrounds per abatement option.

Some factors deserve additional reflection to see how their level of uncertainty can be improved in future research.

Factor B4 (responsibility division) shows a similar uncertainty for all abatement options in this research, namely the different frame of reference. This can be clarified by indicating the scale level for this factor (e.g. project level, scaling up in the Netherlands) as well as selecting the actor(s) from which this question should be reasoned from.

For factor D1 (awareness of actor) uncertainty arises from a difference of scale. Illustrations of these factors can be clarified by selecting the actor(s) from which this question should be reasoned from.

For factor D2 (frequency of opportunity) the definition of the factor should be clarified as a difference in understanding is noted for this barrier.

Recommendations are presented in chapter 5.

4.6.3 Missing barriers comparison

From the literature review, several potential candidates were selected as missing barriers. The interviewees also named several missing barriers. Public acceptance (I) and policy uncertainty (II) will be discussed in this section. Table 4.9 shows an overview of how many interviewees mentioned a certain missing barrier.

Table 4.9 Comparison of missing barriers

Insulation	Carbon Capture Storage	Biofuels	Geothermal energy	Potential factors from literature review (Chapter 2)
Influence of the social environment (1x)	Societal perception and acceptance (1x) Public support (1x) Political support (1x)	Public perception (1x) Public opinion (1x)	Societal acceptance (1x) Political or (local) public support (1x)	Public acceptance I
		Strong interests of incumbents and path dependency (1x)	Risk specific per region (1x)	Lack of infrastructure
	Policy uncertainty on the long-term (2x)	Policy uncertainty* (1x)	II	Lack of institutions

* Concept was mentioned but not as missing barrier

** Lack of skills was a candidate factor from the literature review which was already added after the literature review to the definition of barrier B3 (types of actors)

I: Public acceptance: This barrier is mentioned by half of the interviewees from different abatement options. It is also a suggestion concluded from the literature review. Therefore, it is worth to consider adding this concept to the Y-factor. To increase the clarity of this concept, public acceptance is defined as 'the favourable reception of an abatement option by a community'[2]. Devine-Wright (2007) uses the following scales for the implementation of renewable energy technology: "micro (at single building or household level); meso (at the local, community or town level) and macro (at large scale 'power station' level)" (Devine-Wright, 2007, p. 8). These scales could be used to evaluate which community should be evaluated in discussing public acceptance problems in the abatement option under investigation. For geothermal energy, the local community was mentioned by interviewee 11 as a suitable group to evaluate for this topic. However, he does mention that a local project may become the stake in a national debate resulting in another actor group to evaluate. The evaluation group for biofuels would be the Dutch population, as the increase of biofuels at gas stations would be a national operation. This paragraph showed a short reflection on public acceptance, which is a complex research topic itself that gained an increased attention over the past years.

It is recommended to explicitly add this concept, so users of the Y-factor recognise this issue as part of the method. Hence, the following change is suggested:

- Adding public acceptance in the definition of B3 (types of actors). A high score should be given if there is (a **potential** for) a lack of (local) **public acceptance or support**. This lack of acceptance indicates that interventions are needed (e.g. (local) stakeholder management supported by a well-designed stakeholder involvement process).

[2] This definition was constructed by combining the definitions of 'public' (adjective, of, relating to, or affecting a population or a community as a whole) and 'acceptance' (noun, favourable reception; approval; favour) from (Dictionary.com)

It is dissuaded to create a different factor for this topic, as it includes only two types/groups of actors, namely the initiator(s) and the (local) public. This makes the factor different from the other factors in the multi-actor complexity category, which are aimed at evaluating the full actor-network for the abatement option .

II: Policy uncertainty and lack of institutions: These concepts are both related to the category of multi-actor complexity. Policy uncertainty is a barrier that can only arise over time when policy is changed often or described or executed differently than expected by the project initiators. This is reflected in a high dependence on other actors (B1) or responsibility unclear (B4), as regulation is changing. The focus of the Y-factor is indicating barriers where potentially policy can be aimed at. Evaluating the stability of policy in the same method would lead to indistinctive results.

The manner in which the other mentioned missing barriers are reflected in the Y-factor is discussed in the sections related to the abatement options

.

4.6.4 Links between barriers

The interviewees were asked to indicate links between barriers. These were also noted during the interview when interviewees made links during their explanation of their barrier scores. A visualisation of the most common links is shown in figure 4.6. Some links are cause-effect relations, others show pairs which often both score high as these represent characteristics of the abatement option.

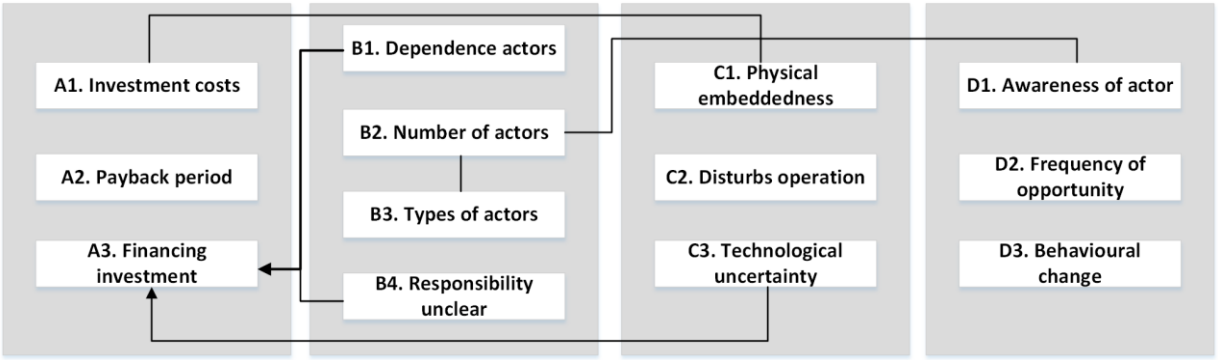

Figure 4.6 Common links between Y-factor barriers

Common links

B1 -A3: A common dependency on other actors is one of financial nature, such as a subsidy or a bank loan (all researched abatement options)

B2 – B3: When there is a high number of actors, a large variety in the types of actors is often seen (insulation and biofuels).

B1 & B4 – A3: Uncertainty on permit procedures or long-term policy and indistinctness in responsibilities between parties are risk factors for banks to provide loans for abatement options (Carbon Capture Storage, Biofuels, Geothermal energy)

B2 – D1: Low awareness when a large group of actors has to take action for the abatement option (insulation, biofuels)

C1 – A1: If infrastructure has to be built it is often intrusive for the environment. Building infrastructure often brings along high costs. Costs reductions are possible when infrastructure can be reused (carbon capture storage)

C3 – A3: The risk of technological uncertainty (e.g. geological uncertainty) makes it more difficult to finance a project (geothermal energy)

The links provide insights into the complexity of the different abatement options. Some links could be found in different abatement options, which shows certain more generic 'couples' of barriers. Some cause-effect relations were also observed (marked with an arrow). Links often show the 'core problem' of the abatement options in this research, which makes them an interesting topic when analysing barriers for abatement options.

4.6.5 Barrier score stability over the past decade

The interviewees were asked to describe the changes of the barriers with respect to ten years ago. The aim of this question was to be able to identify if barrier scores change in within this timeframe.

In three out of four cases, no substantial changes for category A (costs and financing) were named by the interviewees. One interviewee mentioned in the geothermal energy case that the investment costs have increased due to more safety measures that must be taken for drilling. However, subsidy schemes have also been implemented for this technology to make it financially attractive to drill a well.

In category B (multi-actor complexity) some changes which influenced the multi-actor complexity took place for Carbon Capture Storage. The recent focus on cooperation with industrial clusters leads to an increased complexity, for instance, constructing a network instead of a pipeline.

In category C (physical interdependencies), no large changes have taken place. The technological uncertainty has been reduced slightly by more experience in practice in geothermal energy projects.

In category D (behaviour) the changes mostly relate to factor D1 (awareness of actor) as the urgency of acting on climate change increased over the last years according to interviewees from different abatement options. Also, the abatement options geothermal energy and CCS have become known by potential initiators.

Most barrier scores have been stable during the past decade in the researched abatement options. This means can be seen as rather fixed characteristics of the abatement options. Interventions which were introduced have not been able to drastically change the barriers for most of the abatement options.

However, when looking at two other abatement options which were not selected in this research, wind and solar energy, large changes with respect to costs have taken place (International Renewable Energy Agency [IRENA], 2018). Most factors could be influenced by policy, only factor B2 is a rather static factor. Only when the choice is made to not address the topic on a household level, but on a level with fewer actors (e.g. biofuels).

4.6.6 Interventions categorisation

In appendix C.2 the interventions that were mentioned by the interviewees have been categorised in regulatory, financial and informative interventions. Next to this, a division is also made in interventions which are currently in use and which are not (yet) in use / in development.

From this categorisation the following conclusions could be drawn:

- It can be noticed that many barriers have a mix of the type of interventions (financial, regulatory or informative) which can influence them. To illustrate, knowledge exchange on geothermal energy projects can reduce the risk of projects (technological uncertainty C3) which makes it easier to finance these (A3, difficulty in financing).

- Many of the interventions for Carbon Capture Storage and Biofuels are not yet in use, while this is not the case for insulation. This relates to the adoption rate of biofuels and the current absence of CCS-projects in the Netherlands.

- A recurring conclusion in the researched abatement options was that initiating actors (or relevant stakeholders) possessed a low knowledge level on the abatement options. The intervention to increase this level of knowledge is to provide more information to these actors, ranging from companies to citizens. Many methods exist to communicate this knowledge to relevant actors. However, these actors may be easily overwhelmed by this information as many abatement options are likely to get attention in the nearby future.

The government should consider carefully which information will be communicated to prevent citizens and companies from being overburdened with information. One communication strategy is to spread information locally. An example is geothermal energy, where information can be dispersed on a city or neighbourhood level. When it is expected that the choice to support an abatement option can become part of the national debate, local distribution of information may not be sufficient. Communicating to the heterogeneous group of actors (households and car owners in this thesis), the challenge is to develop a scalable communication strategy that appeals to this diverse group.

4.6.7 Barrier importance quantification

The interviewees were asked to grade the barriers according to their importance in impeding the materialisation of the abatement option. No clear conclusions could be drawn from this analysis, as the variance of the grading between interviewees was rather large and several interviewees mentioned that this question was difficult to understand. They also mentioned a certain bias of high grades for high barrier scores. The analysis can be found in appendix C.3.

Weight system

The design of a weight system for the different barriers could provide more insight into the relative importance of the barriers. It can direct the user of the Y-factor to the most relevant barriers for the abatement options. It is expected that two or three different weights would be sufficient. A large system can harm the summarising overview that the Y-factor provides. A large weight system may also lead unwanted discussions on details. It is also unlikely that a system with two or three weights shows as much variance in the range of scores as the grading did that was used in this research. When developing such a system it must be clarified that the weights indicate the relative importance and the barrier scores indicate the extent to which a barrier is present.

It is not recommended to expand or further quantify definitions under 'low', 'medium' and 'high' It is expected that this would lead to discussions on if the characteristics of the abatement options fit in the Y-factor categorisation. To compare abatement options, the supporting stories should be analysed. One way to find interesting comparisons is to select abatement options with similar scores, as similar problems may be present.

4.7 Conclusion Results

In this chapter the interview results per abatement option were presented (section 4.2: Insulation, 4.3 Carbon Capture Storage, 4.4 Biofuels and 4.5 Geothermal energy). The insights into the four abatement options have been compared in section 4.6. The interview reports from the expert interviews are the main data source of this chapter and can be found in appendix B. Supporting analyses for conclusions in this chapter can be found in appendix C.

Figure 4.7 provides an overview of the barrier scores that were concluded from the expert interviews. The variance in scoring is reflected in the uncertainty of the concluded score.

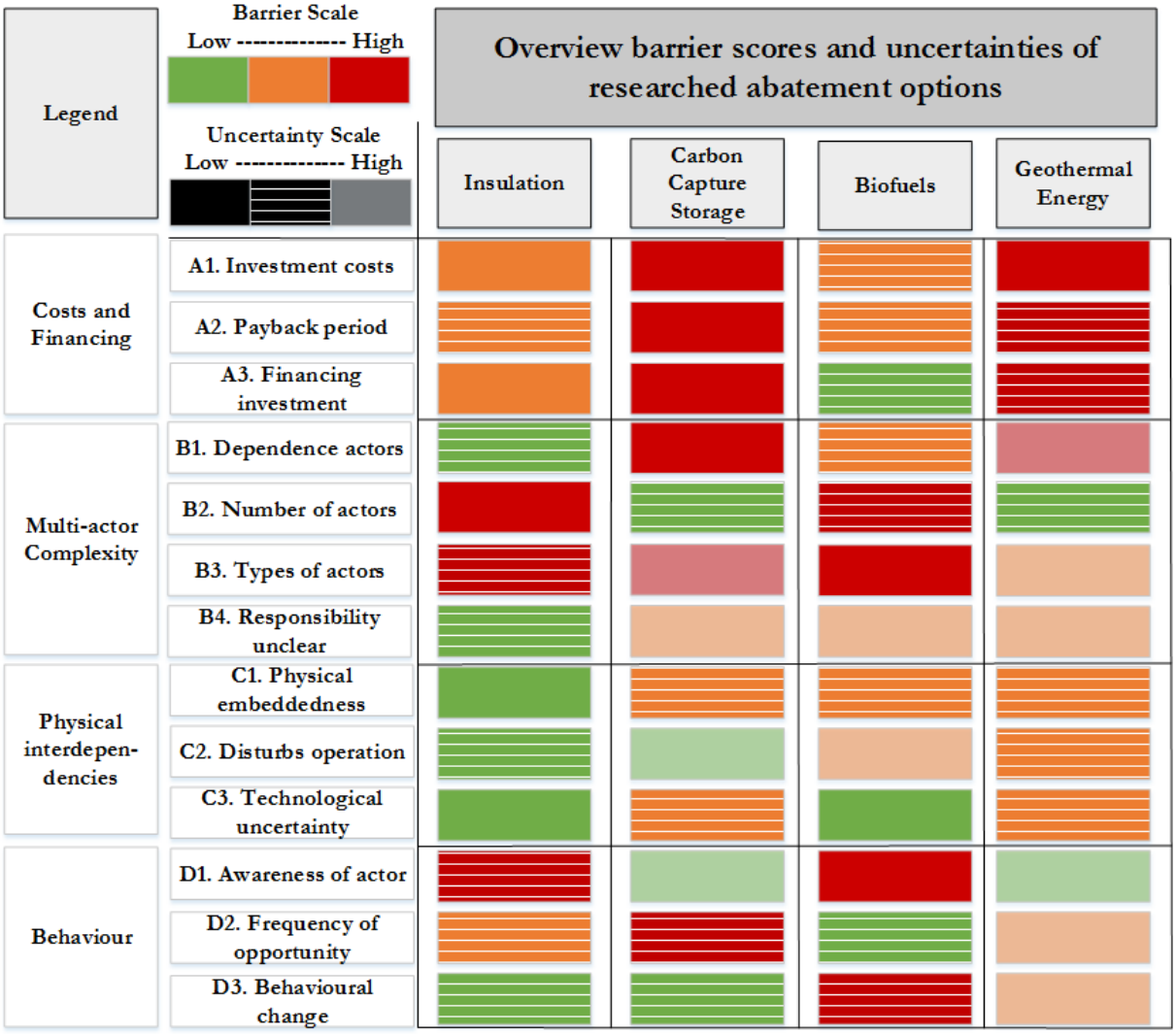

Figure 4.7 Barrier scores and uncertainty of four abatement options

Main barriers of the four abatement options

Short summaries of the abatement options explain the reasons of impediment of materialisation and support the barrier scores. These summaries also underpin the relevance of the Y-factor barriers.

Insulation

The most important barriers for insulation are: the number of actors (B2), types of actors (B3) and the awareness of actors (D1). The combination of these barriers describes the crux of this case: How to convince a large number of diverse households to take action? Costs and pay-back period are barriers for households as well. Insulation is mostly installed on natural moments, for example when moving to another house or during constructions in their house.

Carbon Capture Storage
The high investment costs with the perspective of no or a long pay-back period make the financial barriers (category A) substantial for CCS-projects. The dependence on other actors (B1) is large with respect to subsidies and permits. The Netherlands also has limited locations (D2) for CCS-projects available due to the set focus of offshore storage and industrial networks. Some technological uncertainty is present, as no full-chain project (capture, transport and storage) has been realised in Europe yet. The separate parts are, however, proven.

Biofuels
The fuel costs of biofuels are higher than fossil fuels which is a barrier for car owners to switch to using biofuels. The number of actors (B2) which would have to make a change is large, as well as the diversity of this group (B3) and their cars. Only gasoline cars need to be adapted (C1) to use high blends of biofuels (E85), this is not necessary for the use of biodiesel or bio-CNG. Currently not many Dutch citizens are aware (D1) of the option of driving on biofuels and the fact that it is blended in small proportions in their current fuel. Good cooperation in the production chain is necessary to scale up production. It is yet unclear how the costs and benefits will be divided over the chain (B1).

Geothermal Energy
The high investment costs together with the long pay-back period lead to the substantial financial barriers (category A) for geothermal projects. The dependence on other actors (B1) is large with respect to subsidies and permits as well as the fact that horticulturists often work in a consortium to finance the construction of a geothermal source. The largest source of uncertainty comes from geological uncertainty (C3). What is found in the underground determines the output of the geothermal source. Different authorities are involved in the permit procedure and as the geothermal energy sector is young, some regulations can still be refined to increase the clarity for project initiators (B3, B4).

Comparison of narratives abatement options
Two challenges were concluded from the comparisons of the four researched abatement options. The main challenge for abatement initiated by households is to adequately inform a large heterogeneous group to convince this diverse group to act. The main task to stimulate materialisation of capital-intensive abatement options is reducing the uncertainty on the investment from for instance regulations or geology.

Methodological insights
The analysis of the interview reports led to a deeper understanding of how the barriers specifically reflect in the abatement options. Next to this, it also led to a number of methodological insights.
- Difference in scale levels in Category B Multi-actor complexity (Insulation)
The barriers in the multi-actor complexity category evaluate actors on different levels. In B1 (dependence on other actors), this dependence is evaluated on a project level, in B2 (number of actors), the number of initiators which is needed to reach the potential of an abatement option in the Netherlands is evaluated.
- Lack of knowledge or awareness (D1) (Carbon Capture Storage)
Interviewees mentioned a difference between knowledge on an abatement option and awareness of the abatement option. Awareness is seen as a low level of knowledge, the actor 'has heard of' the abatement option. With knowledge the interviewees meant that the actors know what steps should be taken to implement the abatement option or if this abatement option is feasible for their property/business.
- Difficulty of scoping (Biofuels)
It was hard for interviewees to evaluate the abatement option biofuels as this entails a production chain of gathering raw materials, processing, distribution and consumption. The focus of the interview was on consumption (the private car owner changes to biofuels), although the existence of the chain is a requirement for this consumption. The interviewees argued that the scores would be different when the focus on another part of the chain was chosen.
- Relevance of scoping (Geothermal Energy)
One interviewee on this option showed the relevance of scoping by indicating the difference of the project scopes between geothermal energy in a horticultural environment and in the built environment. This focus leads to a difference in barrier scores.

Several of the other methodological insights into the Y-factor relate to the sources of uncertainty that were analysed in this chapter and will be discussed in the next paragraph.

Sources of uncertainty
The narratives and the scoring of the barriers for one abatement options showed variance amongst the interviewees and thus led to uncertainty in the conclusions on these barriers. Five sources of uncertainty have been identified:
- Different frame of reference: This is the most common source of uncertainty. The barriers were discussed on different scale levels, for instance on a project scale or national upscaling of the abatement option.
- Ill-fit with Y-factor categorisation: The cost structure of changing to biofuels (low/no investment, high operational costs) is difficult to capture in the Y-factor barriers.
- Different understanding of barrier: Several interviewees asked for additional explanation about barrier D2, frequency of opportunity. The stories on this factor differed nonetheless from 'a project can start everyday' to relating the start of a project more to 'natural moments' or certain boundary conditions that should be present.
- Perception of barrier: The perception of a barrier is as relevant as the 'objective' barrier (e.g. X activities will take place which give nuisance Y). The way in which this nuisance is experienced, or the actor thinks he/she will experience it, is relevant for the existence of a barrier. The objective evaluation of the hindrance of these activities does not show the real barrier that the actor experiences. This perceived barrier is relevant as the actor has to take action to implement the abatement option.
- Similar arguments, different conclusion: This uncertainty is not explicable from the comparison of the answers of the interviewees. The different conclusions might result from unspoken comparisons with other abatement options or recent experiences. It may also be caused by different types of expertise from the interviewees. Some interviewees also indicated that they possessed different level of knowledge on the different categories.

Table 4.10 shows the recommendation on the clarification of factors that resulted from the analysis.

Table 4.10 Recommendations clarification of factors.

Barrier	Source of uncertainty	Recommendation
B4 (responsibility unclear)	Different frame of reference	Define scale level (project, national) and actors to evaluate from
D1 (awareness of actor)	Different frame of reference	Define which actors should be evaluated
D2 (frequency of opportunity)	Different understanding of barrier	Sharpen definition barrier

Missing barriers
It is recommended to add the barrier 'public acceptance' explicitly to the definition of barrier B3 (types of actors) to clarify that this type of conflict of interests is included in the Y-factor. Half of the interviewees mentioned a missing barrier related to 'public acceptance' and this concept was also concluded from the literature review as a potential missing barrier.
Policy uncertainty was mentioned by three interviewees and resulted from the literature review. It is dissuaded to explicitly add this barrier to the Y-factor. This topic is reflected in the barriers dependence on other actors (B1) and/or responsibility unclear (B4), where the government does not provide a long-term vision.

Links between barriers
Links often show the 'core problem' of the abatement options in this research, which makes them an interesting topic when analysing barriers to abatement. Next to this, the links between barriers provide insights into the complexity of the realisation of the different abatement options. Some links were identified in different abatement options, which shows certain more generic 'couples' of barriers. (B1 – A3, a dependency on other actors with respect to the difficulty in financing). Some cause-effect relations were also observed. If for example the regulations in a sector are clear (B4, responsibilities unclear low) and long-term policy is set out, it is easier for initiators of projects to gather sufficient financial means.

Stability of barrier scores
Most barrier scores have been stable during the past decade in the researched abatement options. This means these could be seen as rather fixed characteristics of the abatement options. Interventions that were introduced have not been able to bring large changes to the barriers for most of the abatement options. However, when looking at other abatement options outside the scope of this research, significant cost cuts can be observed for wind energy and solar energy. The stability of barriers and how these can be influenced could be a topic for further research.

Categorisation of interventions
A mix of the type of interventions (financial, regulatory or informative) can influence the different barriers. A barrier in the category of multi-actor complexity can, for instance, be reduced by both regulatory and informative interventions. Next to this, it is also noted that it is difficult to develop scalable interventions when a large number of actors (e.g. households) must take action for an abatement option to materialise as these all have different interests as well as different equipment/houses/cars.

Conclusion: Proposed method to investigate barriers
In the interviews, the barriers have first been discussed to learn about the complexity of the abatement options. The additional questions on missing barriers, links between barriers, developments of the last decade and potential interventions provided a more insight into the complexity of materialisation. These had been chosen to learn more on the barriers itself such as common links or overlap, robustness of barriers and preliminary steps in linking interventions to barriers for policy evaluation. The grading of barriers did not lead to conclusive results on importance. Quantification by a simple weighty system can potentially provide more information on relative importance of barriers.

It is recommended to use the aforementioned steps in researching abatement options with the Y-factor as these proved to deliver a rich understanding of barriers to materialisation of abatement options.

5. Discussion

In this chapter, first an elaboration on the sources of uncertainty for variance in barrier scores is presented (5.1). This is followed by recommendations with respect to scoping of abatement options (5.2) and clarification of barrier definitions (5.3). The insights into barrier scores are generalised in section 5.4. Preliminary results are presented (5.5) followed by a reflection on comparing and prioritising abatement options and what this implies for the policy arena (5.6). The chapter closes with reflections on the research (5.7) and direction for future research (5.8).

5.1 Discussion sources of uncertainty

As discussed in section 4.6.1 variance was observed in the barrier scores and supporting stories of the interviewees. These stories, however, gave explicit input for the barriers, which showed the rationale behind the score. From the analysis several sources of uncertainty could be identified: Different frame of reference (5.2), Different understanding of barrier (5.2), Ill-fit with Y-factor categorisation (5.3), Similar arguments, different conclusion and Perception of barriers. The brackets indicate in which section these will be addressed, the last two sources of uncertainty are addressed in this section.

Similar arguments, different conclusions

The source of uncertainty 'similar arguments, different conclusion' means that the reason for the difference in scoring cannot be derived from the story of the interviewees. This is expected to come from implicit knowledge. Several interviewees also mentioned during the interview or before the interview that it was not easy to select the scores, some also gave scores 'in-between' the categories (medium-high). Some also mentioned that they made implicit comparisons to other CO_2 abatement options, although the focus of the interview was on one abatement option. It may also result from different types of expertise from the interviewees. Some interviewees also indicated that they possessed different level of knowledge on the different categories.

Perception of barriers

The perception of a barrier is a relevant underpinning for the existence of a barrier. In the interviews on insulation an interesting observation was made on the perception of barriers. Due to lack of knowledge the households perceive a high barrier to, for example, disturbance from the installation of insulation. This barrier can be reduced by providing more information on the actual disturbance. This does not mean that a perceived barrier is lower than an 'objective' barrier (e.g. high investment costs of millions of euros). If a barrier results from ignorance of the initiator on the abatement option, it is as much as a barrier as an 'objective' barrier. The most suitable intervention for this barrier may be different. For disturbance of the installation, extra information provision can reduce the barrier instead of changing something on the installation process in a technical sense.

Subjectivity in scoring of interviewees

It can be expected that this perception of the height of a barrier also plays a role when experts are asked to score barriers. Their scores could be partly subjective due to their expertise or specific experiences. The story behind the score should always be present to underpin the score and provide transparency and comparability of scores between abatement options. When differences in scores arise, the researcher can interpret the stories and conclude the most logical from the comparison of the stories.

5.2 Scoping of abatement options

In this section, recommendations on the scoping of abatement options are described. Additional scoping is expected to reduce uncertainty originating from the 'difference in reference frames'. It may also reduce the number of issues where uncertainties were noted related to 'similar arguments, different conclusion'. It also leads to a better understanding of the abatement option as experts can discuss the issues more specifically. When larger scopes are chosen, the information becomes more generic (e.g. geothermal energy in general or detailed to 'developed by horticulturists' or 'developed in the built environment'). An overview of the recommended scoping steps is shown in figure 5.1

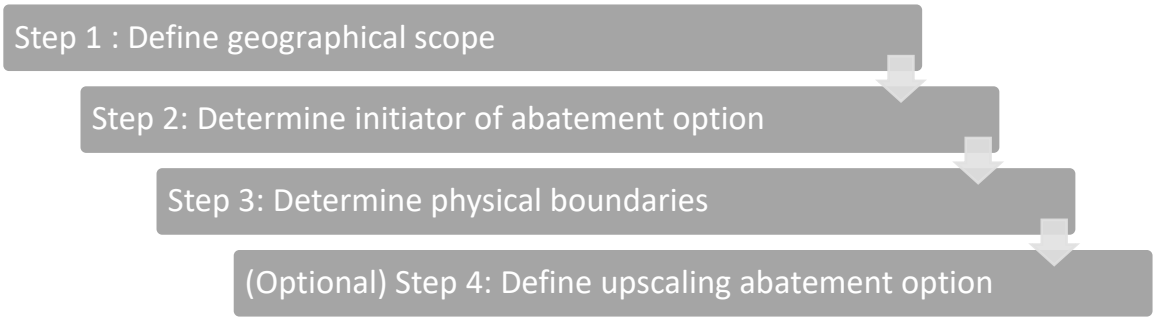

Figure 5.1 Recommended scoping steps

Step 1: Define geographical scoping

It is recommended to scope on a country-level. The scoring in category B, multi-actor complexity depends on regulations, which can differ between countries. The dependence on other actors (B1) can be different with respect to the necessary permits or available subsidy scheme. According to interviewee 6 the power of different actors also depends on culture. The geological characteristics of a country can also have an influence on the scoring. For example, the availability of empty gas fields can influence the locations for Carbon Capture Storage and the seismic risk within the country can constrain the locations for Geothermal Energy. The density of population of a country can also constrain the implementation of abatement options due to public resistance which may occur (e.g. onshore windfarms).

Step 2: Determine initiator of abatement option

The choice of the initiator of a project should be part of the scoping phase. The initiator/responsible party should be clear to score barriers: B1 (dependence on other actors), B4 (responsibility unclear) and D1, awareness of actors. The choice of the initiator of a project steers which group of actors is evaluated.

An example is the development of geothermal energy in the built environment as presented by interviewee 12. Municipalities are not aware of the heat network which is necessary, and many house owners are not aware of the impact of this source of heating. (Heat) network operators, which can be initiators for a project, are however aware of the implications of using geothermal energy for heating. Another example of the necessity to choose an initiator is in the abatement option of insulation. When the choice was made to focus explicitly on tenants, the barrier structure would be different. If the tenants initiate this project the dependency on other parties (owner of the building) is much higher than in case of a private home owner who wants to insulate its home. It is also important to relate the investment costs to the initiator of the project. A geothermal project is incomparable to an insulation project with respect to investment costs, although initiators both perceive financial barriers.

Step 3: Determine physical boundaries

To create clarity on category C (physical interdependencies) it is necessary to physically define the project. Wind offshore most likely has different barriers than wind onshore (different actors involved, different costs). Geothermal Energy in a horticultural environment has a different barrier structure than implementing it in the built environment (where a heat network is needed with the corresponding disturbance), as indicated by interviewee 12. The interviewees on the abatement option biofuels also addressed this topic as the barrier scores differ within the production chain. For example, biofuel factories face differences in investment costs, dependencies and awareness of option biofuels in comparison to a household which changes to drive on biofuels.

(Optional) Step 4: Define upscaling abatement option
For some of the barriers, it is necessary to define the abatement option that is referred to in the definitions of the barriers. For most barriers this seems to refer to realising a 'project' through implementing the technology (e.g. insulating one house, driving on biofuels, building a CCS-project, constructing a geothermal well). This led to some difficulty for barrier B2 (number of actors) and B4 (responsibility unclear). For B2, when reasoning on a project level, the number of actors can never be millions. Furthermore, the impact on the system (e.g. fuel system) is limited when one car owner changes, but substantial when millions change. For B4, some interviewees illustrated this barrier with indistinctness on who is responsible for upscaling of an abatement option in the Netherlands while others referred to the responsibilities on a project level. This scoping step is optional as it is suggested to remove barrier B2. Uncertainties regarding barrier B4 may also be solved by scoping step 2 (define initiator of abatement option) as this can indicate the level of reference as well.

5.3 Recommendations on improvement the Y-factor definitions

Next to additional scoping, some suggestions for adapting the definitions of the Y-factor are presented in this section. These definitions should reduce the uncertainty due to 'different understanding of the factor' and 'different reference frames'. A reflection of the uncertainty source 'ill-fit with the Y-factor' is also part of this section.

Category A: Costs and financing
The barriers in this category were clear to most interviewees. Two suggestions are:

- Changing barrier A2 to 'Expected pay-back time' and omitting the stated CO_2-price of 0 euro/ton. The current policy is recommended to be taken as a given while scoring abatement options. When evaluating the pay-back period under the current regime, it can be noted that when a high score is present for the payback period, either a higher CO_2-price would be beneficial or an increased subsidy for the abatement option.

- It is suggested to rephrase barrier A3 'None' to 'Low' and 'Large' to 'High' to be scores of A3, as this increases the clarity: low difficulty and high difficulty.
The suggestions are reflected in table 5.1

The cost structure of the abatement option biofuels was difficult to fit in the barriers of category A (source of uncertainty: ill-fit with y-factor categorization). Currently the investment costs are almost absent and the operational costs (fuel costs) are structurally higher than the conventional fuels. A payback period is not relevant in this case. A change in barrier definitions is not preferred as this source of uncertainty was only found in this abatement option. A suggestion to show this structure would be a high score on the payback period and low scores in other barriers in category A.

Table 5.1 Refining definitions of category A, costs and financing

A. Costs and financing	Low	Medium	High
A.1 Investment cost required	Absent	Medium	Large
Degree to which the investment in an abatement measure is significant			
A.2 Expected pay-back time ~~at 0 euro/ton~~	< 5 years	5-12 years	>12 years
Expected time required to earn back the investment for an abatement measure			
A.3 Difficulty in financing investment	~~None~~ **Low**	Medium	~~Large~~ **High**
The degree to which it is difficult to finance the abatement or attract appropriate financial means			

Category B: Multi-actor Complexity
The barriers B1, B3 and B4 in this category were clear to most interviewees. Several interviewees interpreted B2 on a project level, although it is meant on a larger scale 'How many 'initiators' need to take action for this abatement option to flourish?' Next, one interviewee said that the quantification of 'millions' suggested that 'many' would be thousands, so he ended in 'few'. Suggestions to clarify the barriers are:

- B1, change 'None' to 'No', 'Few' to 'Little' and 'Many' to 'Much' to focus on discussing the dependencies on other actors. Interviewees were inclined to name all involved actors instead of specifically the dependencies on these actors.

- Removing barrier B2 'Number of actors' as the height of this barrier is often reflected in high scores for the barriers B3 (types of actors) and D1 (awareness of actor). Heterogeneity of actors and low awareness are often problems for abatement options that have to be taken by a large number of actors (household level). The signal for an intervention aimed at a variety of actors would then still result from the Y-factor scoring. Another reason for removing this barrier is that the difference in scale of this barrier with respect to other barriers in category B, led to confusion for interviewees.

- Change the barrier name of barrier B3 from 'Types of actors involved' to 'Diversity of actors involved'. This makes it possible reflect the diversity of households as high, instead of arguing that it is one type of the actors which are part of, for instance, an insulation project. This also leads to the change of 'Few' to 'Low' and 'Many' to 'High'. After the literature review, the diversity in skills between actors was added to the definition.

- For barrier B4 (responsibility unclear), interviewees discussed (next to if the main actor felt responsible) also if the roles within a project were clear. This topic also relates to the concept of responsibility. Unclear roles or responsibilities led to interesting insights into cooperation between different actors and is perceived as a risk. Therefore, it is suggested to change the definition of this barrier from "The extent to which it is clear which actor has the responsibility for the abatement measure" to "The extent to which the roles and responsibilities for the realisation of the abatement option are clear". The barrier name would be suggested to change to 'Division of roles and responsibilities unclear' to adapt it to the changed definition. The topic of who is responsible for the abatement option is also reflected in factor D1 (awareness of actor).

- Half of the interviewees named 'public acceptance' as missing barrier. This is defined as 'the favourable reception of an abatement option by a community' in section 4.6.2. This barrier resulted from the literature review of chapter 2. It is thus worth to consider adding this barrier. It relates well to the multi-actor complexity category, as this barrier is mostly about opposing interests of two actor types, the initiators of the project and the (local) public. This could also be linked to a diversity of interest among involved actors (B3). Therefore, it is suggested to add this concept in the definition of barrier B3. "Degree of diversity of interests, values, roles, skills and expectations of the actors involved. When opposing interests from the (local) public to the implementation of the abatement option are (expected to be) present, a high score should be given'. Opposing interests, especially from the public, can be block the realisation of projects thus should be reflected in this high score. This opposition can be observed by action groups, the presence of many critical questions in local meetings on projects or negative news in the local newspapers. Similar indications of opposition can also be noted on a national level if the abatement option is part of the national debate. As discussed in section 4.6.2 the scale level (micro, meso and macro) of the abatement option determines which actor group should be evaluated.
The suggestions are summarised in table 5.2.

Table 5.2 Refining definitions of category B, multi-actor complexity

B. Multi-actor complexity	Low	Medium	High
B.1 Dependence on other actors	~~None~~ **No**	~~Few~~ **Little**	~~Many~~ **Much**
Degree of dependence on actions of other actors to successfully implement and execute the abatement measure			
~~B.2 Number of actors~~	~~Few~~	~~Many~~	~~Millions~~
~~Number of actors that are required to take action to realise the abatement measure~~			
B.3 ~~Types~~ **Diversity** of actors involved	~~Few~~ **Low**	Medium	~~Many~~ **High**
Degree of diversity of interests, values, roles, **skills** and expectations of the actors involved. **When opposing interests from the (local) public to the implementation of the abatement option are (expected to be) present, a high score should be given'**			
B.4 ~~Responsibility unclear~~ Division of roles and responsibilities unclear	Clear	Slightly unclear	Unclear
~~The extent to which it is clear which actor has the responsibility for the abatement measure.~~ **The extent to which the roles and responsibilities for the realisation of the abatement option are clear**			

The recommendations on the removal of barrier B2 and adding public acceptance to B3 have some implications for the understanding of barrier B3. A high score on B3 can mean that a large heterogeneity in one 'type' of actors is involved (e.g. households) as it can also mean that opposing interests are present (another type of diversity). The supporting story for the score is therefore essential in the understanding of this barrier score.

Category C: Physical interdependencies

The barriers in this category were not the main problem for the implementation of the researched abatement options. A suggested change to increase clarity:

- C1 physical embeddedness, change 'Strongly' to 'High' to get a clear sentence 'high physical embeddedness'. This is visualized in table 5.3.

Table 5.3 Refining definitions of category C, physical interdependencies

C. Physical interdependencies	Low	Medium	High
C.1 Physical embeddedness	No	Medium	~~Strongly~~ **High**
Degree to which the abatement measure requires physical changes to the environment it is placed in			
C.2 Disturbs regular operation	No	Slightly	Strongly
Degree (duration, intensity) to which status quo/regular operation is disrupted to successfully apply the abatement measure			
C.3 Technology uncertainty	Fully proven	Small	Large
Degree to which the technological performance of the abatement measure is uncertain			

Category D: Behaviour

The barriers in this category were not always clear to the interviewees. Therefore, some suggestions on the definitions are presented and summarised in table 5.4

- Interviewee 6 mentioned that in social sciences, a difference is made between 'awareness' (e.g. by asking questions such as: 'Have you heard of technology X?') and knowledge (Questions to test factual knowledge on technology X). This can be translated into being aware of the existence of an abatement option and knowing what it entails to implement the abatement option. This difference can also be observed for insulation, all households have heard of insulation, but there is a lack of knowledge on which steps should be taken to install this insulation. It is suggested to adapt this definition as several interviewees asked for

additional explanation on the notion of 'thinking scope'.

Implementing this notion in the Y-factor definitions is challenging. A high score could be 'no knowledge' or 'not aware'. However, the opposite score described in a sentence would become 'a low absence of knowledge' meaning 'a high level of knowledge'. This double negative can be slightly confusing for the interpretation of the Y-factor. However, the same 'problem' is noted for D2. A 'frequency of opportunity' of 'often' reflects a low barrier. When applying the user must be aware to select the barrier scores by focusing on the category meanings instead of 'high', 'medium' and 'low.

It is recommended to include the notion of the importance of the knowledge level into the Y-factor. The proposed suggestion is to change the name of the barrier from 'outside thinking scope of actor' to 'absence of knowledge of actor' and change the definition from 'Degree of awareness of the parties responsible for the abatement measure' to 'level of knowledge of the parties responsible for the abatement measure'. It is suggested to change the scoring options from 'No' to 'High knowledge level', 'partly related' to 'low knowledge level' and 'outside scope' to 'no knowledge'. A high knowledge level means that the initiating actor knows the business case and steps of implementation of the abatement option on its location. The low means that the initiating actor may have heard about the abatement option (only aware of it), but is not acting to acquire more information as their occupancies are focused on other activities.

- Many interviewees indicated that they faced difficulties in understanding barrier D2 (frequency of opportunity). Although an explanation was given, this led to different answers. This barrier is about the question how often a 'window of opportunity' occurs for the implementation of the abatement option. This window of opportunity occurs when the conditions are right. Examples of conditions can be: sufficient capital available, subsidy available, 'natural moment' of replacement investments, political support or if a suitable location is available. These examples can be shown to clarify the definition of this barrier

Table 5.4 Refining definitions of category D, behaviour

D. Behaviour	Low	Medium	High
D.1 ~~Outside of thinking scope of actor~~ **Absence of knowledge of actor**	~~No~~ **High knowledge level**	~~Partly related~~ **Low know-ledge level**	~~Outside scope~~ **No knowledge**
Level of knowledge of the parties responsible for the abatement measure			
D.2 Frequency of opportunity	Often	Medium	Rarely
Number of opportunities for the responsible party to realise the abatement measure			
D.3 Requires change in behaviour	No	Slight	Severe
Degree to which the actors involved need to change their day to day behavior			

5.4 Generalised insights on barriers from case selection

Direct generalisability of the scores on the four abatement options to for example other countries is limited. Scoping is essential for the understanding of the relevant barriers of an abatement options. Interviewees indicated differences in scoring (and supporting stories) when providing examples from slightly different scopes of the same abatement option. The chosen initiator is relevant for the scores as well as the demarcation to the Netherlands. Regulations may be different in other countries (e.g. extensive subsidy schemes, a different permit system) as well as physical structures in the country (density of population, geology). A different initiator, for instance, a housing cooperation for the insulation case instead of a private home owner, can also lead to slightly different scores. When the differences are known, one could perhaps reason which barrier scores would change and note a justification for the score.

The more high-level conclusions on the case-comparison, presented in section 4.6.1, can be generalised to a larger extent. The challenge of convincing a heterogeneous group of households to take action is relevant in the category 'vehicles' (when it comes to private cars) and the category 'household' (includes e.g. LED-lighting and residential electronics). For capital-intensive abatement options, reducing the uncertainty from multi-actor complexity barriers and technological barriers is essential to stimulate investments. Capital-intensive abatement options can be found in categories such as 'energy', 'CCS' and 'industrial processes'. This last category is not part of the scope of this research, neither are the categories

'forestry', 'agriculture', 'waste' and 'buildings'. The categories were shown in chapter 3 on the case selection. Therefore, it is difficult to say if these high-level conclusions would also be relevant when researching abatement options in other categories.

The methodological recommendations on the Y-factor and the support for the relevance of the barriers can ben generalised to a larger extent. I would expect similar recommendations on scoping and definitions of the Y-factor from a different set of abatement options (assuming the same research method and interview questions would have been used). The insights on links between barriers, robustness, interventions led to an increased understanding of barriers to CO_2 abatement in general. The Y-factor aided in retrieving these insights.

5.5 Preliminary results

The recommendations in this section have been incorporated partly during the research already. Therefore, a reflection is given on the preliminary results that could be concluded from this research by including the recommendations.

In figure 5.2, it can be noted that high scores on B3 are present for all researched abatement options except geothermal energy. Two out of four interviewees on geothermal energy mentioned this missing barrier. As this technology is not yet implemented in the built environment, it is not yet known if public acceptance will be a relevant topic. In the scoping of this research the focus was on the horticultural environment, where the local public is positive about this technology. CCS shows some issues with public acceptance (for onshore projects), but mostly shows a high score due to diverse interests among stakeholders (also in the offshore scope of this thesis). The high score for biofuels and insulation results from the large heterogeneity in households and private car owners. As can be noted in figure 5.2, these high scores go hand in hand with a low awareness of the abatement option (high score D1). Hence, no information is lost due to the removal of B2.

The recommended scoping steps were used in the interviews already as can be noted from the defined scopes of the abatement options in chapter 3. Several interviewees also shared barriers for the abatement option outside the defined scoping resulting from their enthusiasm and expertise on the abatement option. Although the interviewer indicated the scope, the stories were part of the interview and may have led to some of the variance in scoring. This stresses the importance of the scoping steps presented in section 5.2. Together with the suggested clarifications of the barrier definitions (especially B4, D1, D2), this may lead to different barrier scores. The recommendations have therefore been partly implemented during the data collection phase. Hence, the results of the abatement options of this thesis (with omitting B2-scores) can be interpreted as preliminary results.

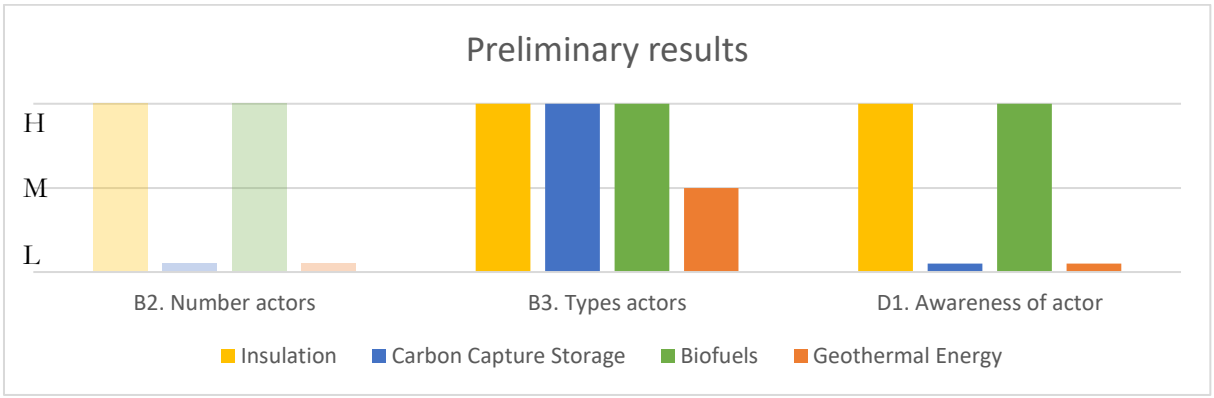

Figure 5.2 Preliminary results visualised

5.6 Implications for the policy arena

Reflections are provided on how abatement options could be compared and prioritised. This shows how the Y-factor can provide input to policy evaluation.

Comparison of abatement options

The barrier scores are determined from the perspective of the initiator of the abatement project. The available budget and the project scale flow naturally from the type of initiator (e.g. business or single household). A high score on the investment costs, for example, can be supported by rather different cost figures. These must, however, be related to the available budget of the initiator. Most barriers are of qualitative nature. This results in the situation that not all 'high' scores have a similar level of difficulty to reduce. This leads to some cautiousness in making one-on-one comparisons of barrier scores between abatement options. The scores do indicate where extra attention or potential stimulating interventions from government are needed. The background story of the barrier scores provides insight into what type of intervention may be effective to reduce the barrier.

Prioritising abatement options

A prioritisation of which CO_2-abatement option should be implemented first, should not be derived from solely the Y-factor scores. The high (and medium) barriers indicate what kind of interventions are needed to stimulate materialisation. It is a political choice what budget the government makes available for these interventions.

When aiming to make a prioritisation, the technological potential of abatement options in one sector should be compared. To translate these into realistic potentials, one needs additional information. The barriers of the abatement options should be combined with the available budget for interventions. From this combination, an estimation of this 'realistic potential' can be calculated. However, one has to take into account that many of the discussed barriers are of qualitative nature, a translation to quantitative data is necessary for the calculation.

5.7 Research reflection

Reflection

- Method: Expert interviews proved to be a labour-intensive manner to gather information. The interview duration of one hour proved to be quite tight to discuss all questions. I do think this was the most suitable method to increase understanding of the Y-factor barriers as interviews provide a rich source of diverse data.

- Scoping: In Chappin (2016) it is acknowledged that barrier scores can vary for different regions and 'we chose the Netherlands or Europe when we were forced to be more specific' (Chappin, 2016, p. 2). In this research some additional scoping was done before starting the expert interviews. During the interviews, I experienced that sometimes extra scoping was needed. The biofuel case, in particular, proved difficult to capture in the Y-factor, as it was hard to leave the production chain out of the barrier evaluation. This led to the insight that scoping is essential to gather rich information on an abatement option, where rich means specific or detailed information instead of generalised information. Recommendations on scoping are presented in section 5.2.

- Case selection: Figure 5.3 shows that no high scores are present in category C. Most interviewees discussed this category quite briefly, it seemed that most issues were found in category A and B. Many interviewees mentioned for barrier C1 that they included the visual aspect of physical embeddedness (change to the environment, C1) when evaluating it, which can be a reason for lower scores. The visual aspect is important in my opinion, as this can influence how people perceive the change of environment to a large extent. However, the figure shows that all barriers were present in the combination of the four abatement options. Hence, information could be gathered on all barriers of the Y-factor.

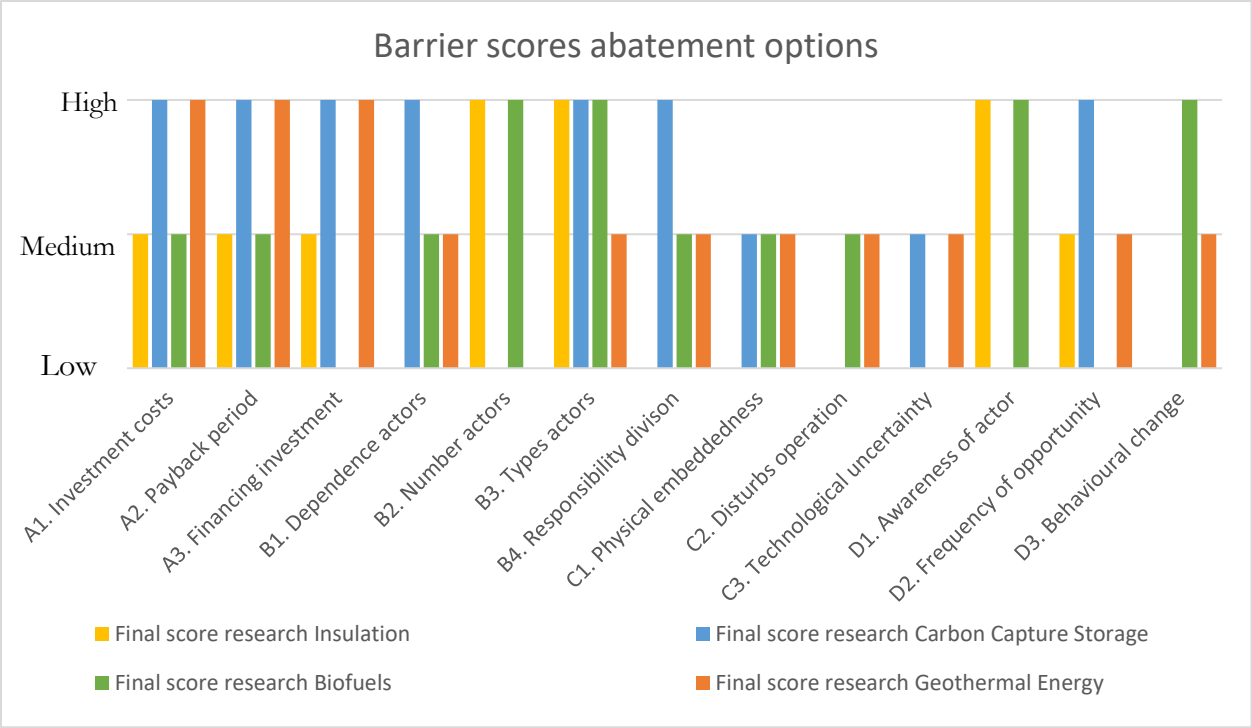

Figure 5.3 Coverage barrier scores of four abatement options

Limitations of the research

- During the analysis, it occasionally proved difficult to find one line of reasoning in the answers of the interviewees. This would be easier when more interviewees per abatement option were interviewed. Interviewing is a labour-intensive research method, hence this was not feasible within the time constraints of this research. However, I do think that the choice of four abatement options with less interviews provided more information than three abatement options with more interviews.

- The list of interventions is an inventory of which options are available to stimulate the materialisation of abatement options. The focus of this study was on finding an underpinning of the barriers and seeing if the issues for materialisation could be captured in the thirteen barriers. Therefore, there was less time in the interview allocated to the question on the interventions which are possible to reduce barriers. Some interventions were linked to barriers by interviewees, but the author also performed a part of the categorisation. More focus on finding out if experts see links between barriers and interventions would be an interesting topic for further research.

- "In-between scores" (low/medium instead of low or medium) led to some noise in the results. It would have been better when interviewees would have been forced more to stick to the three categories of low, medium and high.

- Occasionally additional scoping was needed within the interview as it turned out that within one abatement options, the barrier stories can be rather different. Stricter scoping before starting the interviews would most likely have led to more similarity in the answers.

5.8 Recommendations for future research

Future research on understanding barriers to CO_2 abatement could have different directions.

- Research could explore how the Y-factor can be used in policy evaluation. In this thesis preliminary steps have been taken by linking interventions to Y-factor barriers. It would be interesting to compare abatement options that had a 'break-through', an acceleration in implementation, and compare these to abatement options that are not yet materialised. This comparison can also be made when differences between countries on the uptake of abatement options are analysed. The analysis of the interventions or causes that led to this break-through (and to which barriers these related) may provide input on building an 'intervention strategy' that can push the materialisation of an abatement option.

- Follow-up research could also be directed towards comparing abatement options within one sector. This may provide additional insights to the comparison that was made in this thesis where options from different sectors have been compared. Several questions may be answered: Do options in one sector show similar barriers? What is the cause of differences? Can barriers be reduced on a sector level?

- A last suggestion is the addition of a weight system to the Y-factor. This could provide more insight into the relative importance of the barriers. In this research, first the weight system should be designed. The design could be tested by comparing different abatement options. The added value of this addition could be shown by the additional insights that result from the weights and if (and how) these vary between different abatement options.

6 Conclusion

The main research question of this thesis is:

How can the understanding of the barriers to CO_2 abatement in the Netherlands be improved?

This research consisted of a literature study and expert interviews on four abatement options where the Y-factor was applied. The analysis of the interviews led to various insights on barriers and resulted in recommendations on using the Y-factor and the research into barriers to CO_2 abatement in general. These steps will be discussed by answering the sub research questions as defined in the introduction.

6.1 Literature review

The sub research question for the literature review is:

Can the Y-factor barriers be supported by literature relevant to materialisation barriers?

Three types of literature sources have been researched. .

- Marginal Abatement Curve critics. The Y-factor aims to complement the analysis of the MACC. It manages to do so as it is more transparent and covers additional barriers related to costs, multi-actor complexity, physical interdependencies and behaviour. The set of thirteen barriers acknowledges complexity as it elaborates on the technological potential and project costs that are shown in the MACC.

- IPCC report: This internationally acknowledged climate report is written by a large number of researchers and therewith summarises the most up to date knowledge on climate change. The abatement options are classified per sector, which also includes barriers to materialisation. These barriers could support the relevance of the four barrier categories of the Y-factor, however lacked detail to support the full set of Y-factor barriers.

- Theoretical frameworks: A comparison to theoretical frameworks from transition literature showed that he Y-factor barriers are more specified and operational than the elements of the theoretical research frameworks. Hence, the Y-factor can be classified as a research method. The RET-framework of Painuly (2001) is most similar to the Y-factor. It shows an exhaustive list of barriers where the user should select relevant barriers and further specify these. The Y-factor, on the other hand, aims to compare abatement options using thirteen barriers in four categories.

The four barrier categories of the Y-factor could be supported by the researched literature. The more operational nature of the Y-factor leads to a classification as a research method.

6.2 Abatement options selection

The following question was leading for the case selection:

What is a representative set of case studies for CO_2 abatement in the Netherlands?

A multi-criteria selection process was applied to select four abatement options from the fifty options that were evaluated by Chappin (2016). His scoring of the abatement options provided input for the selection procedure.

Step 1: Exclude non-relevant abatement options for the Netherlands
Step 2: Exclude actively implemented abatement options in the Netherlands
Step 3: Exclude lowest three Y-factor scores
Step 4: Exclude packages of measures
Step 5: Select abatement options from different sectors

This led to the selection of the following CO_2 abatement options:

- **Insulation**: Focus on private home owners and houses with cavity wall and floor insulation possibilities
- **Carbon Capture Storage**: Focussed on industrial parties/networks and full-chain projects of CO_2 capturing, transport and (offshore) storage
- **Biofuels**: Focus on private car owners and biofuels with a high percentage of bio-based raw material
- **Geothermal Energy**: Focus on horticulturists as project initiators that change to geothermal energy for heating their greenhouses

The selected abatement options are part of different sectors: the built environment, industry, transport and energy. All Y-factor barriers are indicated by Chappin and could be researched. Hence, this selection is concluded to be representative.

6.3 Expert interview analysis results

Three or four expert interviews per abatement option have been conducted to learn about what the materialisation barriers entail in the research options and how this translates to barrier scores in the Y-factor. With this information the following research questions is answered:

What are the Y-factor scores for the cases and what is the underlying rationale?

The overview in figure 6.1 shows the barrier scores of the abatement options, including their uncertainty in scoring. The text boxes below the figure illustrate a summary of the rationale supporting the scores.

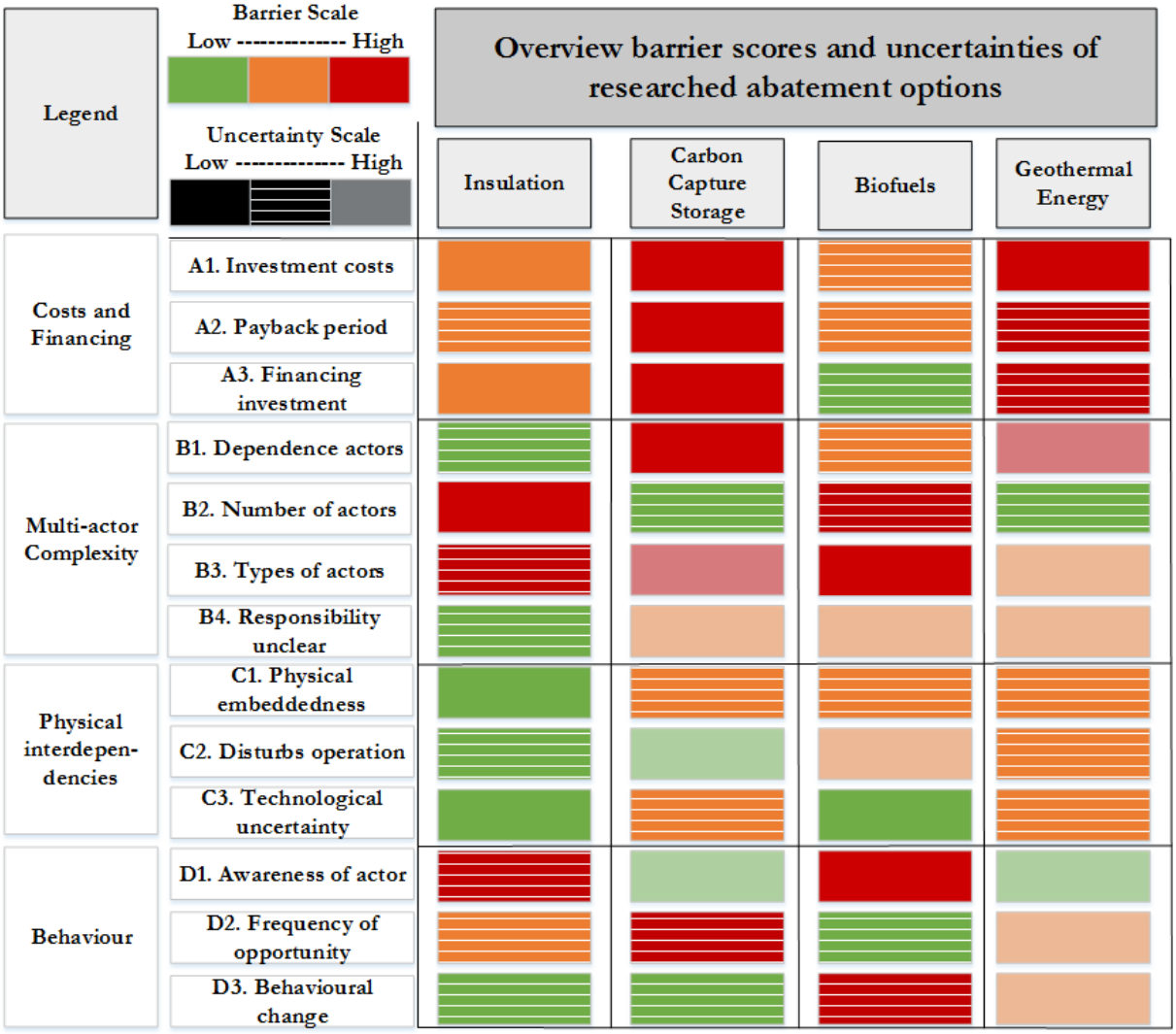

Figure 6.1 Barrier scores of the four abatement options

Insulation

The most important barriers for insulation are: the number of actors (B2), types of actors (B3) and the awareness of actors (D1). The combination of these barriers describes the crux of this case: How to convince a large number of diverse households to take action? Costs and pay-back period are barriers for households as well. Insulation is mostly installed on natural moments, for example when moving to another house or during constructions in their house.

Carbon Capture Storage
The high investment costs with the perspective of no or a long pay-back period make the financial barriers (category A) substantial for CCS-projects. The dependence on other actors (B1) is large with respect to subsidies and permits. The Netherlands also has limited locations (D2) for CCS-projects available due to the set focus of offshore storage and industrial networks. Some technological uncertainty is present, as no full-chain project (capture, transport and storage) has been realised in Europe yet. The separate parts are, however, proven.

Biofuels
The fuel costs of biofuels are higher than fossil fuels which is a barrier for car owners to switch to using biofuels. The number of actors (B2) which would have to make a change is large, as well as the diversity of this group (B3) and their cars. Only gasoline cars need to be adapted (C1) to use high blends of biofuels (E85), this is not necessary for the use of biodiesel or bio-CNG. Currently not many Dutch citizens are aware (D1) of the option of driving on biofuels and the fact that it is blended in small proportions in their current fuel. Good cooperation in the production chain is necessary to scale up production. It is yet unclear how the costs and benefits will be divided over the chain (B1).

Geothermal Energy
The high investment costs together with the long pay-back period lead to the substantial financial barriers (category A) for geothermal projects. The dependence on other actors (B1) is large with respect to subsidies and permits as well as the fact that horticulturists often work in a consortium to finance the construction of a geothermal source. The largest source of uncertainty comes from geological uncertainty (C3). What is found in the underground determines the output of the geothermal source. Different authorities are involved in the permit procedure and as the geothermal energy sector is young, some regulations can still be refined to increase the clarity for project initiators (B3, B4).

6.4 Recommendations on improving the Y-factor

From the analysis of the interview reports, the last sub research question could be answered:
How can the Y-factor be improved based on the obtained insights?

Both the scores and supporting stories of the experts showed variances. These variances arose predominantly from a different frame of reference between the interviewees (e.g. different levels of scale: project or national level). Other less-frequent sources were: an ill-fit with the Y-factor categorisation of case-specifics (mostly biofuels) and a difference in understanding of barrier definitions (mostly D2, frequency of opportunity). For more than one third of the observed variances, no clear reason could be assigned. The different conclusions may have resulted from unspoken comparisons with other abatement options or recent experiences. Another cause could be the different types of expertise of the interviewees.

For the insulation case, an interesting phenomenon was observed. Households expect much disturbance from the installation of insulation, so one interviewee scored this barrier as 'high'. The lack of knowledge on the actual disturbance resulted in this perception of households. Hence, perceived barriers are as important as 'objective' barriers, as these do impede materialisation.

To reduce the variance in scoring in future research, recommendations on scoping and clarification of barrier definitions are presented.

To gather specific stories and scores on the abatement options, scoping with respect to geography (preferably on a country-level) is essential. Regulations as well as physical circumstances (e.g. geological structures, population density) differ between countries. Next, the initiator of the abatement option should be determined. This choice affects the 'actor group' that is evaluated (relevant to multi-actor complexity and behaviour). Changing biofuels for shipping is a different task from changing to biofuels for private car owners. Last, it is important to scope to the physical boundaries. The location where the abatement option is implemented greatly influences the barriers. CCS offshore and onshore show a different situation regarding multi-actor complexity and investment costs.

The most important recommendations to increase the clarity of the Y-factor are the removal of

barrier B2 (number of actors) and adding public acceptance to barrier B3 (types of actors). The characteristic that is caught in barrier B2, a high number of initiators, also reflects in a high score on B3 (large heterogeneity of actors) and a low level of awareness (D1) of this large group. The concept of public acceptance (a favourable reception of the (local) community), is recommended to include in barrier B3. A high score on B3 (types of actors) reflects the presence of opposition from the community. Remaining recommendations focus on clarification of several barrier definitions (B4: responsibility unclear, D1: awareness of actor; D2: frequency of opportunity).

The following steps are recommended to gather specific supporting stories for the Y-factor barriers when researching abatement options. Before starting the study, it is essential to scope each abatement option with respect to: geography (preferably on a country-level), the initiating actor and the physical boundaries of the 'abatement project'. A background story supporting the barrier score is essential to understand the cause of the barrier. One should verify if the Y-factor barriers include all complications of the abatement option to create a complete story. The understanding of the barriers can be increased by investigating links between barriers and analysing if barriers changed over the past years. This offers the possibility to reflect on the robustness of barriers and the effectiveness of past interventions. An overview of current and potential interventions offers options for policy evaluation. A similar approach (without the scoring aspect) could also be used in researching abatement barriers in general.

6.5 Answer main research question

The main research question of this thesis is:

How can the understanding of the barriers to CO_2 abatement in the Netherlands be improved?

In this research the Y-factor was used in expert interviews to gather information on the barriers to the materialisation of four abatement options in the Netherlands: Insulation, Carbon Capture Storage, Biofuels and Geothermal energy. The potential of these options for the Netherlands is relevant, although no acceleration of their realisation has taken place. The Y-factor proved to be a suitable research method to systematically research materialisation barriers from a system's perspective as it included barriers related to costs and financing, multi-actor complexity, physical interdependencies and behaviour. The supporting stories of the barrier scores and links between barriers revealed the complexity of materialisation. Additional scoping of abatement options and clarification of barrier definitions can increase informative value of the supporting stories and increase the scoring quality. Researching abatement options when using a system's perspective can improve the understanding of barriers to CO_2 abatement.

Future research on understanding barriers to CO_2 abatement could have different directions. First, research could explore how the Y-factor might be used for policy evaluation purposes by linking current and potential interventions to Y-factor barriers. Second, abatement options within one sector can be compared to see if similar barriers are observed. An intervention strategy on sector level could potentially be developed. Third, a design could be developed to weigh the importance of barriers in abatement options. This would show where most attention is needed to reduce barriers for an abatement option.

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References to interviewees are reported in appendix B.

Appendices

Appendix A: Scientific paper

Evaluating barriers to CO_2 abatement

C.E.C. Arensman

Faculty of Technology, Policy and Management
Delft University of Technology, Netherlands

Abstract

The Marginal Abatement Cost Curve (MACC) implies that materialisation of CO_2 abatement options is only impeded by implementation costs. This disregards the underlying complexity as non-economic barriers have proven to be relevant. The Y-factor complements the MACC as it includes financial, multi-actor, technical and behavioural barriers. This research applied the Y-factor for the first time in expert interviews on a selection of abatement options. This resulted in generic lessons on barriers to CO_2 abatement as well as lessons specific to the Y-factor. Links between barriers are essential to understand complexity. Also, the perception of barriers from the view of the initiator of an abatement project is relevant for evaluation. Last, scoping abatement options with respect to geography, the initiating party and its physical boundaries is essential to gather specific information on barriers. The Y-factor provides a complete narrative of the materialisation barriers. It indicates where intervention may benefit materialisation and therefore offers possibilities for policy evaluation.

Keywords: CO_2 abatement option; barriers; materialisation; Marginal Abatement Cost Curve; energy transition

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Are investment costs the only barrier to CO_2 abatement materialisation?

In 2009 McKinsey and Company published an overview of the cost and potential of a wide range of CO_2 abatement options with their publication of the Marginal Abatement Cost Curve (MACC) (Nauclér & Enkvist, 2009). Abatement options are ordered in a curve with respect to their costs of materialisation per ton CO_2 emissions reduced. This curve implies to policy-makers that the costs are the only barrier to the realisation of CO_2 abatement options. However, are investment costs the only barrier to impede the materialisation of abatement options?

The options must be implemented in existing technical structures, the living environment of citizens and the current institutional setting of a country or area. This can be illustrated by the realisation of a wind park. When built, the wind park has to be connected to existing technological structures (the electricity network). This intermittent energy source demands additional attention for the network operator. The landscape changes when a wind park is built, which can lead to opposition from local citizens. Permits for the wind park have to be issued by different authorities, the procedures may have long durations. Some uncertainty may also be present on the pay-back period, as the electricity prices are uncertain in the future.

Introducing the Y-factor

Chappin developed the Y-factor, to provide more insight into barriers that may impede materialisation of CO_2 abatement options (Chappin, 2016). With this research method he aimed to complement the analysis of the MACC. He uses four categories of barriers:

costs and financing, multi-actor complexity, physical interdependencies and behaviour. These categories consist of three or four barriers each which adds up to thirteen barriers in total. In appendix I these barriers and their definitions are presented. In this paper, the Y-factor was used as a research method to increase the understanding of the barriers to materialisation of CO_2 abatement.

Complementing the weaknesses of the MACC?

With the Y-factor, Chappin intends to complement the weaknesses of the MACC identified by Kesicki and Strachan (2011). Some of the weaknesses are lack of transparency on assumptions and lack of showing complexity. Several other weaknesses relate to cost definitions, discount rates and showing uncertainty ranges for costs. As the Y-factor does not quantify costs, these last weaknesses related to cost quantification cannot be complemented nor improved by the Y-factor.

The Y-factor shows improvement with regard to transparency in scoring as it uses three scoring options per barrier. This contributes to the understanding of the allocated score. The complexity of the realisation of abatement options is shown by the range of barriers. This can aid a researcher to gather a system's view on the matters that are relevant for the abatement option under investigation.

Structure paper

The remainder of this paper shows the results of the analysis of expert interviews where the Y-factor was applied. First two abatement options are described. This is followed by various more general insights on barriers to CO_2 abatement. In the discussion a reflection is presented on the comparison of abatement options. Last, the conclusion and future research options are presented.

Method

To increase the understanding of barriers to abatement, the Y-factor was applied in expert interviews. The investigated options were: Carbon Capture Storage, Biofuels, Insulation and Geothermal energy. These options are part of different sectors namely industry, transport the built environment, and energy. All options have been scoped geographically to the Netherlands. The last two options will be further elaborated in this paper. Three to four expert interviews per abatement option have been performed. The interview reports supporting the analysis can be found in appendix B.1 and B.4 of (Arensman, 2018)[3].

Results: Insulation and geothermal energy discussed

The complexity of barriers to materialisation is illustrated by presenting the summaries of the abatement options insulation and geothermal energy. The summarised interview results are structured by the Y-factor barriers. The Y-factor scores are presented in figure 1. The thirteen barriers of the Y-factor are presented on the x-axis of this figure, definitions can be found in appendix I.

[3] This thesis is available in the repository of the Technical University of Delft after June 1st 2018. https://repository.tudelft.nl/islandora/search/?collection=education

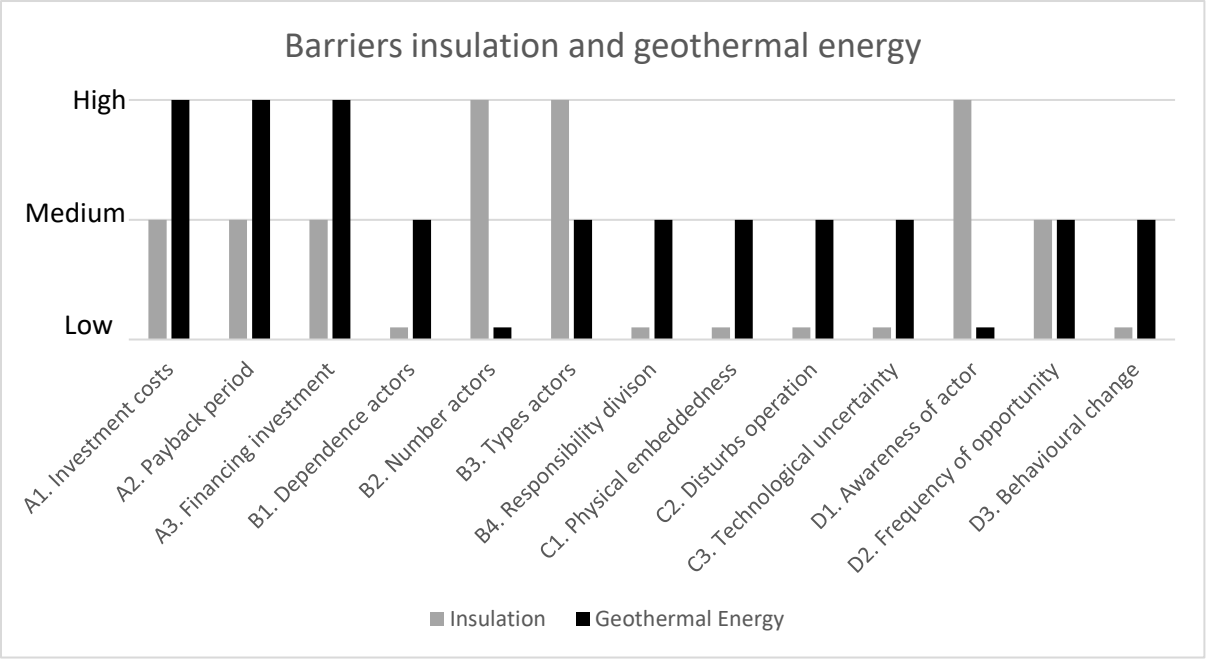

Figure 1: Results Y-factor scores Insulation and Geothermal Energy based on (Arensman, 2018)

Insulation

The scope of the abatement option 'insulation' is private home owners of houses with a cavity wall and where floor insulation can be added in the crawl space. The costs and financing are a relevant barrier to insulation. Investment costs are an important decision-factor for households, although it is a surmountable barrier (A1). Households have difficulties with estimating if they will earn back the investment during the time they own the house (A2). They might move before the payback period of five to twelve years. In the Netherlands, subsidies are present for insulation measures in several municipalities, although it is not easy to get a clear overview of the options (A3).

Home owners can decide to insulate without depending much on other parties, only a constructor must be contacted to execute the works (B1). The decision to insulate must be taken by many households in the Netherlands to result in a significant CO_2 emission reduction (B2). Diverse motives drive this decision (e.g. comfort or financially driven). The household's financial reserves and type of houses also differ (B3). Households do not always feel responsible to reduce their energy usage by insulating their house (B4). Taking the actual step to install insulation is postponed due to various reasons.

The barriers in the category 'physical interdependencies' all show low scores, these do therefore not seem to be the largest hurdle for a household. Adding insulation does not visually change the house of the home owner (when a cavity wall and crawl space are present) (C1). The disturbance of the works is also low, as the duration is short (one or two days). Many households do perceive this disturbance as a barrier due to their lack of knowledge on the exact works (C2). The technological uncertainty on insulation materials is low, as materials have been used for decades (C3).

The lack of awareness is an important reason why home owners procrastinate taking insulation measures or do not take them. Many home owners do not know what the volume of heat that flows from their homes, as it is not visible. For a group of home owners, it also not evident what steps are necessary for the installation of insulation

(D1). Households often take action on natural moments, for instance in combination with other home improvements or when they move to another house (D2). After insulating, the changes to day-to-day behaviour are limited. Only some changes have to be made with respect to ventilation of the house (D3).

Geothermal energy

The demarcation of the abatement option 'geothermal energy' is projects where horticulturists are project initiators that change to geothermal energy for heating their greenhouses. The main barriers for project initiators are the investment costs (A1) (several millions of euros) and the pay-back period (A2) of this investment (between ten and fifteen years). A subsidy on the production of sustainable sources (SDE+ in the Netherlands) is essential to reduce the pay-back period to this duration and therewith build a viable business case. Project costs are often borne by joint-ventures of horticulturists. Banks that offer loans to these joint-ventures perceive the geological risk as most significant. The local geology determines the production capacity of the source.

The dependence on other parties (B1) is large during the preparation phase of geothermal energy projects. Loans have to be acquired from banks, permits from different authorities have to be collected, research on geology must be performed to apply for these permits and the approval from local residents should be obtained. The number of parties involved is limited in geothermal energy projects initiated by horticulturists (B2). No actions from citizens are needed to start a project for horticultural purposes. The diversity of interests (B3) amongst involved actors is a relevant issue. Some duality of interests is also found within organisations. An example is the Ministry of Economic Affairs and Climate. This party decides on the approval of permits according to regulations, while at the same time aims to stimulate the growth of sustainable energy sources in the Netherlands. Some indistinctness of responsibility (B4) is noted for the supervisory authority. As the geothermal energy sector is young in the Netherlands, this party often provides advice to projects in development although this may conflict with their supervisory role.

The visual change to the environment of a geological source is limited (C1). A small building that houses a heat exchange installation does not stand out in a horticultural environment. The structure in the subsurface is not observable in the landscape. The disturbance of the works is limited (C2). Local residents may be bothered by nuisance and some logistical challenges may arise on the terrain of the horticulturists. Technological uncertainty (C3) results from geological uncertainty. The production quantity of the source depends on what is found in the underground.

The option of geothermal energy is well-known by horticulturists in the Netherlands as an alternative to heating with fossil fuels (D1). Geological research is needed to see if the subsurface is suitable for this technology. Location-dependency is thus an important determinant for the number of opportunities of this technology (D2). Occasions to shift to this heating source occur when replacement of the heat source is needed. Next to this, financial reserves must be present as well to be able to start a project. After a geothermal energy source is installed, its geothermal operator has to perform some measurements and maintenance to the source. This does however not impact its day-to-day job substantially (D3).

Insight into barriers to CO_2 abatement

The summarised interviews prove that Y-factor provides insight into barriers to CO_2

abatement. These findings are relevant to both illustrating the value of the Y-factor as well as increasing the more general understanding of abatement barriers. A number of other insights from the analysis of the expert interviews are discussed in more detail in this section.

Large heterogeneous group of initiators

From the analysis of the barriers to insulation, a more general conclusion can be drawn. This abatement option can be characterised by its large number of initiators (households). The heterogeneity of this group is large as these may have different incomes, types of houses, motivations (e.g. financially driven or comfort-driven). It is a challenging task to present information in such a way that it appeals to this group and can draw their attention to this topic. This same challenge is also relevant to other abatement options that demand action from households as it was observed for biofuels as well.

Capital-intensive abatement options

From the analysis of the barriers to the realisation of geothermal energy projects, generic insights on capital-intensive abatement options can be concluded. The high investment costs are a major barrier for geothermal energy projects. It is therefore important to reduce risks that influence these investment costs as much as possible. This stimulates the initiator of the project to take the investment decision. Risks of geothermal energy projects were mostly observed in the dependence on other authorities for permits and the geological uncertainty. This last one is the most important determinant of the production capacity of the geothermal source. This production capacity strongly affects the pay-back period of the investment.

Robustness of barriers

The barriers proved to be stable for the researched abatement options over the past decade in the Netherlands. For example, no large improvements in the payback period were detected. However, major cost cuts have been observed in the past decade for wind energy and solar energy (International Renewable Energy Agency [IRENA], 2018). The stable scores do nevertheless indicate that interventions to reduce barriers of the researched abatement options have not yet led to a 'break-through'.

Links between barriers

Another insight relates to the links between barriers. The relations indicate the complexity of reducing barriers. Two types of links have been noted. The first type is a 'cause-effect' link. An example is the dependence on other actors for geothermal energy. The approval of the large number of permits and their long procedures (B1) are a risk for banks that finance investment (A3) for geothermal energy projects. The second type of link is the 'common couple'. This link is observed when some high scores often occur together. An example is a high score on the number of actors (B2) and a high score on D1 (outside thinking scope of actor). This couple was observed for both insulation and biofuels. Households are the initiators to install insulation, however they are not thinking about taking action on both topics as these are far from their daily routine. They lack knowledge on the amount of heat that is wasted without insulation and sometimes also lack knowledge on which steps to take to install insulation.

Interventions to reduce barriers

In the expert interviews, an inventory of interventions for the abatement options was made, comprised of current and potential interventions. These interventions could be linked to one or more barriers that they could reduce. This offers possibilities for applying the Y-factor for policy evaluation purposes. Some of the interventions aimed at influencing households are labour-intensive, for example door-to-door advice. This makes

them difficult to scale up to reach all Dutch households. Scalability is an important factor when evaluating interventions that must have a large impact.

It was also concluded that an intervention does not always have the same nature as the barrier it aims to affect. The cause for the barrier should be known when an intervention is designed. This is illustrated by an example from insulation. Many household expect significant disturbance from the installation of insulation. This is however not always an informed expectation. A lack of knowledge causes this perception of a high barrier. Hence, an intervention where information is spread on the disturbance can reduce this 'technical' barrier.

Scoping of abatement options

The interviewees on one abatement option provided different scores for several barriers. The difference of reference frame was the largest source of uncertainty that caused this variance. To reduce this uncertainty, demarcation of abatement options with respect to three aspects are proposed.

First, geographical scoping (preferably on a country-level) is needed as this determines the regulations and potential subsidy schemes. The presence of subsidy can make it possible to build a viable business case for an abatement project. The geographical scope also influences the 'physical' frequency of opportunity resulting from, for instance, the geological structure in a country or its density of population. The seismic risk should for example be low for geothermal energy projects.

The focus on the initiator determines which 'actor group' is evaluated. Insulation in a private house is a different case than insulation measures initiated by a housing cooperation or an association of owners in an apartment building. These last initiators are less independent in their decision-making and have a different available budget compared to private home-owners.

Physical scoping is needed as this determines costs, technological complexity and also affects the actor group. A geothermal energy project in a horticultural environment has limited users of the heat, a small heat network might be needed. However, a geothermal energy project in the built environment (neighbourhood) has a larger number of customers for heat resulting in the need for a more extensive (and more expensive) heat distribution network.

Hence, different 'types' of projects of the same abatement technology show substantial differences in the presence of barriers. This is not only relevant to the use of the Y-factor, but also to understanding the realisation of abatement options on a more general level. As barriers can differ for different demarcations of the same abatement technology, this indicates the need for different interventions. It is essential to specify the scope well when discussing an abatement option to prevent misunderstanding.

Public acceptance

In half of the expert interviews the additional barrier of opposing interests on the development of abatement projects was mentioned. The summarising concept of this topic is known as ' public acceptance' (or the lack of it). This can be defined as 'the favourable reception of an abatement option by a community'. The community can be a local community (regional or neigbourhoud level) but can also refer to the national level. To evaluate this topic, the adequate scale of the community should be chosen. One way to choose this scale is to take into account the scale of the abatement option. Devine-Wright (2007) uses the following scales for the implementation of renewable energy technology that can be helpful in defining this scale:

"- micro (at single building or household level); - meso (at the local, community or town level) and - macro (at large scale 'power station' level)" (Devine-Wright, 2007, p. 8).

Specifically for the Y-factor: It is recommended to change the definition of barrier B3 (types of actors) in the Y-factor show the relevance of this barrier more explicitly in this method.

Barrier perception

The Y-factor evaluates categories with mainly qualitative barriers (the pay-back period is the only exception). To provide proof for the selected 'qualitative' scores it is essential to provide arguments or a narrative based on expert interviews or a literature study. This is comparable to the assumptions that have to be reported when using quantitative results in research. The supporting story can also show the real cause of a barrier and is therewith vital to understand the complexity of materialisation.

The supporting story proved to be essential in understanding barriers households perceive for the installation of insulation. With perception it is meant that a barrier is judged as impeding, but when objectively evaluating it this obstacle would not be expected. Translated to the Y-factor, this means a high barrier score is given due to the perception. However, based on facts the barrier score would be low.

This can be illustrated by the disturbance of the installation of insulation. This is perceived as a barrier by home-owners and a reason to postpone an insulation project. In the expert interviews it however was noted that households often lack knowledge on the duration of and mess caused by these works.

The presence of a barrier is evaluated from the initiator's perspective. If this initiator perceives this barrier, then it could be viewed as relevant, since this barrier blocks the materialisation of the abatement option.

Discussion

Comparing abatement options

The notion that barriers are evaluated from the initiator's perspective is relevant when comparing abatement options by using the Y-factor. The investment costs should, for example, be related to the initiating party. A company can finance larger investments than a single household. A high score on this barrier can be supported by a rather different cost figure.

Next, one should also be aware that not all barriers with the same score have a similar 'level of difficulty' to reduce. This results from the difference in nature of the barriers (e.g. financial, multi-actor, technical or behavioural). The supporting stories can indicate the cause for the barrier and therewith provide information on the difficulty to overcome the barrier and the type of intervention needed. Hence, one should be cautious in comparing Y-factor scores one-on-one within and between abatement options. Supporting stories can provide more information on the barrier causes.

Next to comparing abatement options by using the Y-factor, a more generic remark on studying one abatement 'technology' is also of relevance. A geothermal energy project in a horticultural environment is characterised by different barriers than a project in the built environment. The higher number of heat consumers and the need for a heat distribution network ask for a different focus in stimulating these developments. One should thus be careful in drawing conclusions on one abatement option in a generic sense. Scoping is essential for specific results.

Implications for the policy arena

The aforementioned points of discussion are relevant to the use of the Y-factor in the policy arena. The Y-factor should be seen as a method to gather information on the barriers, presented in both scores as well as a supporting story. To come to a policy advice, other information sources should be incorporated in the decision-making process.

First, the technological potential of the abatement options in one sector should be compared. The Y-factor barriers (both high and medium scores) can indicate where additional interventions may be beneficial. The information on the allocated budget for interventions should be combined with the most relevant interventions. From this information a realistic potential can be estimated. For this step, a translation of mostly qualitative barriers to quantitative data should be made. This data is the effect of the proposed interventions on materialisation,

which is the realistic potential. The aforementioned information can be the basis for a political decision.

Conclusion

In this research, the Y-factor, developed by Chappin (2016), was applied in expert interviews to increase the understanding of barriers to CO_2 abatement. The appliance of this method provided a range of insights.

The barriers were illustrated in the interview summaries on insulation and geothermal energy. This shows for these specific abatement options what the barriers entail. When abatement options must be initiated by households, the main challenge is to appeal to and convince a heterogeneous group of actors. For capital-intensive abatement options, the uncertainty around the investment should be reduced as much as possible to stimulate materialisation.

When investigating barriers to abatement, one should be aware that different demarcations of the same abatement 'technology' can show different barriers (geothermal energy in a horticultural environment differs from applying this technology in the built environment). Therefore, it is recommended to scope with respect to geography, the initiating party and physical boundaries of abatement projects to gather specific information.

The barriers to materialisation are perceived from the perspective of the project initiator. Hence, the perception of the initiator on a barrier is as relevant as its 'objective' presence. The barriers should thus be related to the initiator's perception but also to for example its available budget. Therefore, one should be cautious when comparing barrier scores between abatement options.

Finally, some additional insights are presented on barrier characteristics and how these can be used in policy evaluation. Links between barriers have been observed and show the complexity of materialisation. Barriers proved to be robust over the past decade for the reviewed options. High barrier scores of the Y-factor could be viewed as signposts to the focus of interventions. The narrative that supports these barrier scores indicates the barrier cause and provides input for the design of a suitable intervention to reduce this barrier. Hence, the Y-factor results can provide input for policy evaluation.

Future research

Future research on understanding barriers to CO_2 abatement can have different directions. First, exploring how the Y-factor can be used for policy evaluation purposes by linking current and potential interventions to Y-factor barriers. Second, abatement options within one sector can be compared to see if similar barriers are observed. An intervention strategy on sector level could potentially be developed. Third, a design could be developed to weigh the importance of barriers in abatement options. This can show where most attention is needed to reduce barriers to materialisation of an abatement option.

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Appendix I: Y-factor definitions

The definitions in table 1 were used to by Chappin (2016) to construct his reordering of the fifty cheapest abatement options of the MACC of McKinsey. The element 'skills' in B3 was added after literature research in (Arensman, 2018). The values 0, 1 and 2 that were used by Chappin are replaced by low, medium and high.

Table 1 Y-factor including definitions

A. Costs and financing	**Low**	**Medium**	**High**
A.1 Investment cost required	Absent	Medium	Large
Degree to which the investment in an abatement measure is significant			
A.2 Expected pay-back time at 0 euro/ton	< 5 years	5-12 years	>12 years
Expected time required to earn back the investment for an abatement measure			
A.3 Difficulty in financing investment	None	Medium	Large
The degree to which it is difficult to finance the abatement or attract appropriate financial means			
B. Multi-actor complexity	Low	Medium	High
B.1 Dependence on other actors	None	Few	Many
Degree of dependence on actions of other actors to successfully implement and execute the abatement measure			
B.2 Number of actors	Few	Many	Millions
Number of actors that are required to take action to realise the abatement measure			
B.3 Types of actors involved	Few	Medium	Many
Degree of diversity of interests, values, roles, skills and expectations of the actors involved			
B.4 Responsibility unclear	Clear	Slightly	Unclear
The extent to which it is clear which actor has the responsibility for the abatement measure			
C. Physical interdependencies	Low	Medium	High
C.1 Physical embeddedness	No	Medium	Strongly
Degree to which the abatement measure requires physical changes to the environment it is placed in			
C.2 Disturbs regular operation	No	Slightly	Strongly
Degree (duration, intensity) to which status quo/regular operation is disrupted to successfully apply the abatement measure			
C.3 Technology uncertainty	Fully proven	Small	Large
Degree to which the technological performance of the abatement measure is uncertain			
D. Behaviour	Low	Medium	High
D.1 Outside of thinking scope of actor	No	Partly related	Outside scope
Degree of awareness of the parties responsible for the abatement measure			
D.2 Frequency of opportunity	Often	Medium	Rarely
Number of opportunities for the responsible party to realise the abatement measure			
D.3 Requires change in behaviour	No	Slight	Severe
Degree to which the actors involved need to change their day to day behaviour			

Appendix B: Interview reports

As the interviews were conducted in Dutch, this appendix is written in Dutch. The phrases of the interviewees have been translated in chapter 4.

In deze bijlage zijn de samenvattingen van de interviews gevoegd. Deze samenvattingen zijn gemaakt aan de hand van een opname van de interviews. Deze zijn vervolgens naar de geïnterviewde gestuurd, zodat deze de samenvatting kon nakijken en waar nodig aanpassingen kon aanbrengen. In tabel B.1 zijn de geïnterviewde experts weergegeven.

De volgende vragen zijn gesteld tijdens het interview:
1.Wat is uw functie en of ervaring op het gebied van [abatement option]?
2. Zijn er factoren die ik verder kan toelichten?
3. Zijn er factoren die u miste bij het invullen?
4. Zou u per barrière het verhaal kunnen vertellen over hoe u tot deze score bent gekomen?
5. Zou u een rapportcijfer kunnen geven over in hoeverre deze barrière als belemmerend wordt ervaren door de actor die initiatief moet nemen?
6. Zijn er verbanden tussen barrières volgens u? (Deze werden ook tijdens het gesprek bijgehouden)
7. Hoe zagen de barrières er tien jaar geleden uit (per categorie)? Wat zijn de grootste veranderingen?
8. Welke maatregelen kunnen genomen worden om barrières te verlagen? (Per categorie, deze werden ook tijdens de lange vraag bijgehouden als deze genoemd werden)

Table B.1 Overview of the interviewed experts

Date interview	Name + reference number interviewee		Organisation	Type of organisation
Insulation				
14-2-2018	Rens Schipper	1	Energy Cooperation Zoetermeer (DeZo)	Knowledge platform
23-2-2018	Eefje Stutvoet	2	TU Delft, EnergieSprong	Academia
7-3-2018	Marianne de Snoo	3	Municipality of Rotterdam	Government
Carbon Capture Storage				
21-2-2018	Emma ter Mors	4	University of Leiden, CATO (CCS research project)	Academia
27-2-2018	Onno Tillema	5	ROAD-project CO_2-capture and storage in Rotterdam Harbour / ENGIE	Business
2-3-2018	Suzanne Brunsting	6	Energy Research Centre of the Netherlands (ECN)	Research
14-3-2018	Joëlle Rekers en Jeroen Bruijn	7	Ministry of Economic Affairs and Climate	Government
Biofuels				
22-2-2018	Saeda Moorman	8	Knowledge institution for Mobility (KiM)	Policy research
1-3-2018	Eric van den Heuvel	9	Platform Duurzame Biobrandstoffen	Knowledge platform
7-3-2018	Anouk van Grinsven	10	CE Delft	Policy Research
Geothermal Energy				
20-2-2018	Martin Hogeboom	11	Trias Westland (Ultra deep Geothermal project)	Business
27-2-2018	Frank Schoof	12	Platform Geothermie	Knowledge platform
8-3-2018	Mike Woning	13	Deltares, Delft Aardwarmte Project	Knowledge platform
9-3-2018	Mara van Eck - van der Sluijs	14	DAGO (Dutch Association Geothermal Operators)	Branche organisation

B.1 Insulation

Interview Rens Schipper

Isolatie - 14-2-2018 – Zoetermeer
Voorzitter en communicatie DeZo – energiecoöperatie Zoetermeer
Ervaringsdeskundige door isolatie eigen huis.

Factor	Score	Importance
A.1 Investment cost required	Medium	6
De meeste mensen schrikken van de bedragen van de meeste maatregelen, maar vinden deze acceptabel in relatie tot de terugverdientijd.		
A.2 Expected pay-back time at 0 euro/ton	Medium	5
Veel mensen vinden vijf jaar al veel, maar dit is na uitleg voor de meesten acceptabel. Het is voor huishoudens lastig om in te schatten of zij over vijf jaar nog in het huis wonen.		
A.3 Difficulty in financing investment	Medium	7
Afhankelijk van financiële reserves van huishouden.		
B1. Dependence on other actors	Low	7
Het huishouden is afhankelijk van verschillende actoren. Een voorlichtingspartij, bijv een verkoper of een energieloket (geeft producten van verschillende leveranciers weer en geeft onafhankelijke informatie). Betrouwbaar en advies en advies passend bij het huis is hierbij essentieel. Daarnaast zijn nog een installateur en een geldverstrekker (bank, gemeente) nodig.		
B.2 Number of actors	High	8
Miljoenen huishoudens en duizenden VvE's / woningcooperaties moeten actie ondernemen.		
B.3 Types of actors involved	High	6
Grote heterogeniteit: huishoudens vs huurders, idealisten vs economische beslissers, veel mensen zijn 40+ omdat zij vaak het vermogen hebben en een huis voor de lange termijn gekocht hebben.		
B.4 Responsibility unclear	High	3
Onduidelijkheid, er wordt niet echt verantwoordelijkheid genomen. Vele huishoudens wijzen naar de overheid, deze moet voor duurzame opwek en besparing zorgen met hun belastinggeld. De overheid wijst naar de markt en probeert deze te stimuleren door subsidies. De markt neemt geen grote stappen, omdat huishoudens niet gemotiveerd zijn tot het nemen van maatregelen.		
C.1 Physical embeddedness	Low	8
Als het huis geïsoleerd wordt is ook een ventilatiesysteem met evt. een warmtewininstallatie nodig. De visuele impact hiervan is laag. Wel zorgt dit voor lawaai wat voor veel mensen een groot nadeel is.		
C.2 Disturbs regular operation	Low	6
De isolatie van een spouwmuur gebeurt binnen één dag en van een gevel binnen twee dagen.		
C.3 Technology uncertainty	Low	4
Er zijn betrouwbare cijfers vanuit de wetenschap en praktijk over welke energiebesparing er met isolatie gehaald kan worden.		
D.1 Outside of thinking scope of actor	High	9
Mensen zijn niet bezig met nadenken over het isoleren van hun huis. Er zit ook veel minder 'amusementswaarde' in de aanschaf van isolatie dan bijvoorbeeld een auto. Daarnaast zien mensen niet de warmte wegstromen naar de grond of door de muur en is dit dus letterlijk niet in hun zicht.		
D.2 Frequency of opportunity	Medium	5
Isolatiemaatregelen worden genomen op natuurlijke momenten zoals: voor of na een verhuizing, als er iets kapot gaat (bijv. cv). Verhuizing gemiddeld iedere vijf jaar (gekeken op schaal 20 jaar).		
D.3 Requires change in behaviour	Low	3
Vrijwel niet, soms moet de stand van de ventilatie worden aangepast.		

Aanvulling tabel
'Lawaai' is nu onder C1 geplaatst, al is dit niet direct een fysieke verandering aan de omgeving. Idealisme werd de grootste drijfveer genoemd voor het nemen van maatregelen, het ontbreken hiervan kan een barrière zijn. Er werd wel overlap erkend met D1.

Verbanden
Connectie tussen de fysieke kant en het economisch rendement dat gehaald kan worden, 'Wat verdien ik met lawaai' (C1-A2). Afhankelijkheid van bank voor financiering (A3 – B1). Onduidelijk voor huishouden of het zelf maatregelen moet nemen (B4 – D1). 'Alles grijpt op elkaar in.', in het interview werd van de ene naar de andere factor gesprongen.

10 jaar geleden
Technieken zijn niet veel veranderd/verbeterd (C3). De discussie over aardgasvrij en klimaatverandering zorgt dat het probleem meer in de aandacht komt (D1). De cultuurverandering die hier moet plaatsvinden staat alleen nog aan het begin. De publieke opinie moet nog veranderen naar 'het is normaal om je huis te isoleren' / 'je wordt met de nek aangekeken als je een G-label hebt op je huis'.

Maatregelen
<u>Energiecoöperatie,</u> informeren en aansporen
- Energiecafés: Avonden waarin informatie gegeven wordt over technologieën/maatregelen (D1 en B1 onafhankelijke informatie)
- Blok-voor-blok aanpak: mensen doelbewust benaderen om maatregelen te nemen. In samenwerking met energieloket Zoetermeer (D1).
- Energieloket laat keuzes van producten zien, helpt met offertes, nazorg (B1)
- Artikelen publiceren in krant, website, twitter (D1)

<u>Overheid:</u>
- Duurzaamheidscampagnes om bewustwording te vergroten (D1)
- Subsidie uit overheid en gemeente om de markt te stimuleren, tijdelijk maatregel en het potje kan in de loop van het jaar op zijn (A2/3)
- Leningen, ikinvesteerslim en energiebespaarlening (A3), lening verhoogt wel terugverdientijd (A2), heeft nog niet veel bekendheid in Nederland.

<u>Lobby:</u>
- Groningen van het gas af, Van Gas Los, Urgenda zorgen voor meer aandacht in de mainstream media. Dit stimuleert cultuurverandering die zorgt voor een lagere afhankelijkheid van fossiele brandstoffen (D1).

<u>Makelaar:</u>
- Makelaars raden aan om het huis beter te isoleren, zodat een hoger energielabel gehaald kan worden. Zo kan de eigenaar een hogere vraagprijs vragen voor zijn huis. Dit leidt tot direct financieel rendement voor de verkoper (A).

Relatie met andere duurzame maatregelen
Voor veel andere energiebesparende maatregelen gelden dezelfde barrières. Bij sommige technologische ontwikkelingen wachten mensen op nog betere technieken of lagere prijzen waardoor ze hun aanschaf uitstellen (zonnepanelen, warmtepompen).
Een maatregel van DeZo voor het vergroten van het bewustzijn van haar inwoners is ook het opzetten van collectieve zonneparken. Hierin kunnen mensen deelnemen voor financieel rendement en die bijvoorbeeld zelf geen maatregelen kunnen nemen.

Interview Eefje Stutvoet

Isolatie – 23-2-2018 - Delft

Projectleider innovatieprogramma EnergieSprong gefocust op verduurzamen sociale huurwoningen en PhD TU Delft met als onderwerp het versnellen van de transitie naar een energieneutrale bestaande huizenvoorraad in Nederland

Factor	Score	Importance
A.1 Investment cost required	Medium	8
Wordt naar gekeken, afweging of je het ervoor over hebt. Mensen willen er wel voor betalen, geen onoverkoombare belemmering. Er wordt voornamelijk naar de investering gekeken door beslisser.		
A.2 Expected pay-back time at 0 euro/ton	Medium	6
Over de berekening van terugverdientijden is vaak wat argwaan bij huishoudens. Wel worden terugverdientijden of rendementen vaak genoemd bij isolatiemaatregelen. Isolatiemaatregelen worden voornamelijk genomen om het comfort van het huis te verhogen, in plaats vanuit een geld gedreven motief (hoge energierekening).		
A.3 Difficulty in financing investment	Medium	5
Investering valt mee. Er zijn wel subsidiepotjes te krijgen, maar het overzicht daarin is lastig (groenlening, subsidie), wat wel belemmerend werkt.		
B.1. Dependence on other actors	Low	3
Niet echt een groot probleem. Een huishouden kan zelf de beslissing nemen. Het is vaak niet overzichtelijk naar wie je toe moet gaan voor isolatiemaatregelen en wie wat aanbiedt. De sociale context is hierbij belangrijk, bijv. aan familie of buurman 'naar wie ben jij geweest?'. Als je meerdere maatregelen wil nemen moet je naar veel verschillende partijen toe, er is niet een partij die alle verschillende maatregelen aanbiedt.		
B.2 Number of actors	High	8
Actie van iedere burger in Nederland is nodig om dit uit te voeren. (zie aanvulling onder tabel)		
B.3 Types of actors involved	Medium	6
Wat zijn de uitvoerende partijen, en welke zijn de beunhazen en goede partijen? Bij Vve's heb je veel verschillende huishoudens die samen moeten beslissen of zij maatregelen willen nemen.		
B.4 Responsibility unclear	Low	3
Het is wel helder wie de verantwoordelijkheid heeft, maar of ze deze ook pakken is een tweede. Zeggen is niet per se doen. Bij de echte beslissing in bijv. Vve's gaan mensen dan denken van wat heb ik er zelf aan? Bij sociale woningbouw is het weer anders, huishoudens zeggen 'dat is de verantwoordelijkheid van de woningcorporatie', maar als deze dan iets aan de woning wil doen dan is er af en toe weerstand van 'het is mijn woning'. Hier zie je dan vaak een spanningsveld.		
C.1 Physical embeddedness	Low	7
Niet een hele grote verandering, qua wat er fysiek aan de woning moet gebeuren. Dit hangt wel af van het type woning (bijv. monumenten lastiger), maar bij het grootste deel van de woningvoorraad valt het mee. Geluid van ventilatie wordt als belemmerend ervaren. Perceptie van het nemen van isolatiemaatregelen is anders, dat het wel een grote impact heeft.		
C.2 Disturbs regular operation	High	8
Dit is een van de grootste redenen dat mensen het niet doen, vanwege overlast en rommel tijdens de uitvoering. Huurders vinden de uitvoering van de maatregel vaak ook vervelend.		
C.3 Technology uncertainty	Low	5
Er is nog wel ontwikkeling, maar dat hebben mensen niet echt door. Een tijd geleden is er iets mis gegaan met balansisolatie, als hier een slecht verhaal over in het nieuws komt zagen ze hier wel dat hier in andere projecten ook vragen over gesteld worden door huishoudens.		
D.1 Outside of thinking scope of actor	High	8
Hele belangrijke, sociale context van belang. Particulieren moeten altijd zelf het initiatief nemen.		
D.2 Frequency of opportunity	Low	4

Hoe vaak wordt het aangeboden: vanuit de markt is er een continu aanbod. Voor sociale huur krijg je maar één keer een aanbod 'we gaan nu renoveren, doe je mee'. Natuurlijke momenten: verhuizen of als er verbouwd wordt. Gemeentes met wijkaanpakken: je kunt nu meedoen.		
D.3 Requires change in behaviour	High	7
Als er een nieuw ventilatiesysteem geïnstalleerd wordt, moeten mensen anders omgaan met het openzetten van ramen. Hier zijn de mensen niet van op de hoogte en het kan weerstand oproepen bij mensen als deze denken dat ze hun ramen helemaal niet meer open mogen zetten.		

Aanvulling op tabel

De meeste factoren zijn duidelijk geformuleerd. Het is alleen soms moeilijk om naar low medium high te kijken. Moet hierbij gekeken worden tov andere CO_2-uitstoot verminderende maatregelen of puur naar isolatie en de categorieën die onder low, medium high genoemd worden?

B2 was niet helemaal duidelijk als factor. Dit werd geïnterpreteerd alsof het gelinkt was aan B1 (afhankelijkheid van actoren), dus van hoeveel actoren afhankelijk ipv hoeveel de maatregel moesten nemen. Tussen B3 en B1 werd ook een connectie gemaakt: in welk opzicht zijn de actoren als genoemd bij B1 divers? Hierbij kan het huishouden als een beslisser gezien worden. Wordt er echter gekeken naar de hele groep huishoudens (zoals bedoeld bij B2), dan kan de diversiteit er anders uitzien.

In de tabel is bij een aantal factoren aangegeven hoe de barrière anders kan zijn voor verschillende type woningen/organisaties: monumentale panden, Verenigingen van Eigenaren of sociale huurwoningen.

Missende factor

De ervaringen met isolatie in de directe sociale omgeving (buren, vrienden, familie) is belangrijk voor mensen om de maatregelen te nemen. Ze horen er dan over en kunnen vertrouwen op het advies van hun sociale kring voor het kiezen van de uitvoerende partij. 'Het advies van de buren wordt sneller opgevolgd dan dat van een techneut. De buren worden als meer vertrouwd gezien'. Het is niet altijd een puur rationele keuze of huishoudens maatregelen nemen. Vaak is dit een combinatie van wat je in je omgeving hoort, om de energierekening te verlagen en vooral om het comfort in het huis te verhogen. Dit linkt deels aan D1, maar niet geheel omdat het aspect van vertrouwen op het advies van de buren niet gedekt wordt door deze factor. Andere energiebesparende maatregelen voor huishoudens zoals zonnepanelen worden wel vanuit geld gedreven motieven genomen.

Verbanden tussen factoren

De sociale omgeving is een belangrijke motivator voor het nemen van maatregelen. Deze kan een slechte ervaring hebben gehad met isolatiemaatregelen, door bijv. verkeerde installatie van de ventilatie door de installateur (C3 – B1). Dit zorgt ervoor dat zij hun omgeving geen positief verhaal vertellen over isolatie. Bij isolatie is ook altijd ventilatie nodig. Dit zorgt ervoor dat mensen hun ramen minder vaak open hoeven te zetten en soms de perceptie hebben dat ze deze niet meer mogen openzetten. Deze gedragsverandering kan ook tot weerstand leiden (C1 – D3).
Het is voor huishoudens vaak een stap om over te gaan tot de uitvoering van de isolatiemaatregel, zeggen is nog niet per se ook doen. Dit komt vaak vanwege het opzien tegen de uitvoering (C2 – B4).

Veranderingen ten opzichte van tien jaar geleden

Isoleren wordt al gedaan vanaf de jaren '70. In het begin waren er nog een aantal technische ontwikkelingen nodig. In de jaren '80 hadden mensen vaak last van het 'sick building syndrome', door isolatie was er geen frisse lucht meer in het gebouw. Dit is door ventilatie toe te passen opgelost. Tien jaar geleden waren er ook nog een aantal kinderziektes met balansventilatie, maar hier is ondertussen ook veel ervaring mee.

Bij andere energiebesparende maatregelen zoals zonnepanelen is er in de afgelopen tien jaar wel veel technische ontwikkeling geweest. Zonnepanelen worden tegenwoordig vanuit een financieel motief aangeschaft en niet per se meer vanuit een duurzaamheidsmotief. De sociale perceptie is 'zonnepanelen kunnen geld opleveren'. Woningen met zonnepanelen worden tegenwoordig ook sneller verkocht. Isolatie is nog geen pre voor huizen, dubbel glas is wel de norm geworden.

Woningcoöperaties ondernemen al jaren acties op dit onderwerp vanuit maatschappelijk en financieel oogpunt. Het type maatregelen dat zij nemen verandert wel, vroeger werden losse maatregelen genomen, nu vaker totaalaanpakken (meerdere energiebesparende maatregelen tegelijk). Er wordt tegenwoordig ook meer gerenoveerd in plaats van dat er gekozen wordt voor het slopen van woningen.

Maatregelen om barrières te verlagen
- Bij het nemen van energiebesparende maatregelen bij huishoudens maakt het vrijwel niet uit wat je doet, maar vooral hoe er in het proces voor en tijdens de uitvoering van de maatregelen met de bewoner omgegaan wordt. Dit geldt vooral voor projecten voor huurwoningen. Veel contact met bewoners is belangrijk, uitleg over de werkzaamheden en wanneer deze plaatsvinden, wat de overlast kan zijn, wanneer de bewoners nieuwe informatie krijgen. Het technische verhaal is minder belangrijk voor de bewoners. Het is belangrijk dat het duidelijk is voor de bewoners op welke punten er meebeslist kan worden. Dit waren onder andere de uitkomsten van het rapport 'Derde succesfactor ontrafeld' van ECN, waarbij deze succesfactor het proces is (ECN, 2017).
- Vanuit het innovatieprogramme EnergieSprong zijn ook renovatiewinkels opgestart, welke vergelijkbaar zijn met energieloketten. In deze winkels kan de consument het totaalaanbod zien van energiebesparingsmaatregelen en aanbieders, zodat de consument niet alle verschillende aanbieders bij elkaar hoeft te zoeken. Deze winkels/loketten bieden ook: financieringsmogelijkheden, het regelen van vergunningen, advies over welke besparende maatregelen samen genomen kunnen worden. (B1 en A3).

Interview Marianne de Snoo

Isolatie - 7-3-2018 – Rotterdam
Gemeente Rotterdam bij afdeling stadsontwikkeling - intern ingenieursbureau Rotterdam. Werkzaam in Europees project Triple-A wat gefocust is op het stimuleren van particuliere eigenaren van eensgezinswoningen tot het nemen van energiebesparende maatregelen.

Factor	Score	Importance
A.1 Investment cost required	Medium	9
Dit hangt af van het soort huis dat je hebt, de te treffen maatregel en hoeveel een huishouden te besteden heeft. Mensen zien deze investering als een barrière, omdat ze hun geld maar één keer uit kunnen geven: "Wil ik liever op vakantie of investeren in isolatie?"		
A.2 Expected pay-back time at 0 euro/ton	High	7
Dit is afhankelijk van je huis (leeftijd, eerder genomen maatregelen). Mensen hebben ook vragen als 'woon ik hier nog wel over zoveel jaar'. Voor spouwmuurisolatie geldt een vrij lange terugverdientijd.		
A.3 Difficulty in financing investment	Medium	5
Gemakkelijk als je hiervoor eigen geld beschikbaar hebt. Subsidiemogelijkheden verschillen per gemeente. Rotterdam had een isolatiecoupon beschikbaar om mensen een subsidie te geven als zij isolerende maatregelen troffen. Uit eigen ervaring kan het subsidieproces lastig zijn, soms moet een aannemer een actie doen om de subsidie te krijgen, deze moet hier dan wel van op de hoogte zijn.		
B.1. Dependence on other actors	Medium	2
Afhankelijk van aannemer en evt. energieadviseur. Als een huishouden deelneemt aan collectief inkopen actie is deze ook afhankelijk van andere huishoudens om te willen investeren in isolatie. Buren en vrienden spelen een belangrijke rol bij het motiveren van mensen om maatregelen te nemen. Bij woningcoöperaties moeten huurders samen naar de coöperatie toegaan om deze te overtuigen van het nemen van maatregelen.		
B.2 Number of actors	High	10
Om alle huizen in Nederland te isoleren moeten miljoenen mensen (overtuigd worden om) actie te nemen. Het is moeilijk om iedereen aan te spreken. (Op de schaal van een individueel huishouden zijn de actoren beperkt).		
B.3 Types of actors involved	High	6
Een aantal betrokken actoren zijn: Woningcoöperaties, woning-eigenaren, eigenaar die huis verhuurt, aannemers, energieadviseurs, vve's, overheid (subsidies, stimulering). De bewoner heeft informatie nodig voor zijn besluit, de motivaties kunnen divers zijn (comfort, verlagen energierekening). De energieadviseur wil zijn kennis delen, de aannemer heeft een economische motivatie en de overheid wil de klimaatdoelen van Parijs halen.		

B.4 Responsibility unclear	Low	3
Het is voor de eigenaar duidelijk dat deze verantwoordelijk is voor de isolatie van het eigen huis en de aannemer voor het goed aanbrengen van deze isolatie.		
C.1 Physical embeddedness	Low	3
Uitgaande van een huis met spouwmuur en kruipruimte, valt de fysieke ingreep mee en is deze niet te zien. Zonder spouwmuur en kruipruimte is de ingreep groter.		
C.2 Disturbs regular operation	Low	2
Beperkt. Enkel een gaatje boren in de spouwmuur en de korrels erin doen. Onder de vloer in de kruipruimte kan vloerisolatie worden aangebracht.		
C.3 Technology uncertainty	Low	1
Het concept van vloer en spouwmuurisolatie bestaat al lang en de werking is volledig bewezen.		
D.1 Outside of thinking scope of actor	Medium	9
Awareness is zeker een barrière, de eerste A van het project TripleA staat ook voor awareness. Mensen zijn zich er niet bewust van dat hun huis 'zo lek als een mandje' is. Awareness gaat hier ook breder, bewustwording creëren over de klimaatdoelen. Om awareness onder de gehele bevolking te bereiken moet de boodschap aangepast worden aan het type mensen dat je wilt bereiken. 'Ik gooi geld weg als ik mijn huis niet isoleer' 'hele klimaat in mijn huis wordt beter, de schimmel gaat ook weg' 'ik wil mijn verspilling tegengaan'. Het is moeilijk om een grote groep aan te spreken. Er is bij veel mensen wel een latent bewustzijn, maar echt de stap zetten om maatregelen te nemen wordt om tal van redenen uitgesteld. Onder andere wordt vaak genoemd dat mensen het 'gedoe' vinden, er is vaak een misperceptie over hoeveel rommel het aanbrengen van maatregelen teweegbrengt. Ook weten mensen soms niet welke stappen ze moeten doorlopen voor het nemen van maatregelen.		
D.2 Frequency of opportunity	Medium	2
Je kan altijd de aannemer opbellen om maatregelen te nemen, dit heeft het gevaar dat je het makkelijk kan uitstellen. Met collectief inkopen of subsidieregeling/ inschrijven tot een bepaalde datum wordt een soort urgentie gerealiseerd. Makelaars kunnen advies geven over maatregelen om huizen beter verkoopbaar te maken. Vaak worden maatregelen genomen bij belangrijke momenten in het leven van mensen als er al verbouwingen zijn. De fysieke impact van spouwmuurisolatie en vloerisolatie zijn redelijk beperkt, waardoor 'meeliften' op een verbouwing niet per se nodig is.		
D.3 Requires change in behaviour	Low	2
Nee, gedrag is wel een belangrijke component in energiebesparing, maar niet per se bij isolatie.		

Aanvulling tabel
- De tabel is ingevuld voor een huis met een spouwmuur en een kruipruimte.
- "Isolatie is niet sexy, zonnepanelen wel". Niemand ziet het als je korrels in je spouwmuur stopt.
- B2 werd geïnterpreteerd als op de schaal van het huishouden. Het invullen van low medium en high was soms lastig, het is relatief wat hoge en lage barrières zijn. Schaalniveaus zijn ook belangrijk bij het interpreteren van de barrières.
- Geen missende factoren.

Verbanden
Of een huishouden isolatiemaatregelen alleen kan financieren bepaalt ook in hoeverre zij de investeringskosten als een drempel zien (A1, A3).
Bij collectieve inkoop worden de investeringskosten lager als men met een grote groep inkoopt (A1, B1). Men is wel afhankelijk van de keuze van de andere huishoudens die moeten beslissen mee te doen met de collectieve inkoop.
Mensen hebben de perceptie dat het nemen van maatregelen meer gedoe en rommel geeft dan daadwerkelijk het geval is (C1, D1).
Geld kan maar één keer worden uitgegeven, dit zorgt voor uitstelgedrag voor het nemen van maatregelen (A, D1)

Veranderingen ten opzichte van tien jaar geleden
De urgentie om iets te doen aan klimaatverandering wordt meer gevoeld dan tien jaar geleden. Toen was

het nog veel meer een discussiepunt of er wel iets aan te doen was. Het is tegenwoordig ook "hipper" om als individu iets aan milieu te doen. Duurzaamheid was tien jaar geleden een vies woord, het is nu iets waar meer mensen zich mee bezighouden. Maatregelen worden genomen vanuit een duurzaamheidsmotief of andere motieven (comfort, economisch).

Maatregelen

- Acties voor collectief inkopen verlagen de kosten voor huishoudens om maatregelen te nemen (A1, A2) en zorgen voor een wij-gevoel wat de drempel verlaagt (D1).
De gemeente kan deze acties faciliteren door mensen bij elkaar te vinden die mee willen doen aan dergelijke acties om zo sneller tot koop over te gaan en de afhankelijkheid van de keuze van andere huishoudens te verkleinen (A3, B1).
- De gemeente is bezig met stappenplannen om mensen te informeren over wat ze moeten doen als ze isolatiemaatregelen willen nemen (D1).
- Door subsidies kan urgentie gecreeëerd worden om maatregelen te nemen 'potje is bijna op' (D1). Subsidies zorgen ook voor lagere investeringskosten en een kortere terugverdientijd (A1, A2)
- De Woonwijzerwinkel, het regioloket voor duurzaam wonen, geeft onafhankelijke informatie en heeft energieadviseurs die thuis langs kunnen komen om advies te geven. Ook is in de winkel een aantal materialen tentoongesteld (B1).
- In Rotterdam is een aantal keer een Pop-upshop in winkelcentra gezet vanuit de woonwijzerwinkel. Op deze manier is de drempel voor mensen verlaagd om hier een bezoekje aan te brengen. Er werden ook wijkacties georganiseerd en warmtefoto's van huizen gemaakt, welke men in de pop-upshop kon bekijken. Zo konden ze zien hoe de warmte uit hun huis 'lekte', deze kan je in de popupshop bekijken. Mensen hebben een verliesaversie. Ook gebruikt de woonwijzerwinkel een klantvolgsysteem waarmee deze kan zien of mensen ook echt maatregelen nemen.
- Mensen worden ook aangespoord om maatregelen te nemen door langs de deuren te gaan om informatie te geven.
- De gemeente Rotterdam beschikt over een database van Motivaction over de levenshouding van mensen in verschillende wijken. Op deze manier kunnen zij de boodschap over isolatie aanpassen aan het type mensen dat hier woont (bijv. 'goed voor milieu' of kosten besparen) maar ook hoe deze mensen gemotiveerd kunnen worden (bijv. energieprestatiegarantie afgeven, voor mensen die op zoek zijn naar zekerheid, of subsidies voor economisch gemotiveerde mensen, veel ontzorgen).
- Het is ook een belangrijke keuze via welke kanalen mensen deze boodschap ontvangen. Wel of juist niet vanuit de gemeente bijv. of wie stuur je langs de deur? (bijv. een bekende Nederlander).

B.2 Carbon Capture Storage

Interview Emma ter Mors

Carbon Capture Storage - 21-2-2018 – Leiden

Universitair docent aan de Universiteit Leiden. Senior onderzoeker en projectleider CCS in het CATO-programma (publieke perceptie, 2004-2014) en het EU-onderzoeksprogramma ALIGN CCUS (sociaal-wetenschappelijk onderzoek maatschappelijke acceptatie op projectniveau en in het algemeen, 2017-2020).

Factor	Score	Importance
A.1 Investment cost required	Medium/High	8
Vrij hoge investeringskosten (wel afhankelijk van over welk type project we het hebben). Het aanleggen van nieuwe transportleidingen is relatief duur, het is nog onduidelijk wie hierin moet investeren (waarschijnlijk publieke partij). Dit is waarschijnlijk goedkoper als bestaande gasinfrastructuur kan worden gebruikt. De kosten voor de 'capture' van CO_2 zijn ook nog hoog, en als het primaire industriële proces aangepast dient te worden bij een puntbron dan brengt dit ook kosten met zich mee. CCU kan de capture kosten verlagen.		
A.2 Expected pay-back time at 0 euro/ton	High	8
Dit is een duidelijk probleem voor CCS, het rondkrijgen van de business case. Het ROAD-project (demonstratieproject) is vanuit de bedrijven met name gestopt vanwege een negatieve businesscase. Momenteel wordt een nieuwe business case onderzocht in de Rotterdamse Haven. Bij de eerstvolgende CCS-projecten in Nederland is naar inschatting van diverse partijen (zie te verschijnen CCS Roadmap) een subsidie nodig, omdat de investeringskosten hoog zijn en de CO_2-prijs nog niet hoog genoeg is. Voor CCU is wel een businesscase zonder subsidie mogelijk.		
A.3 Difficulty in financing investment	Medium/High	8
Bedrijven staan niet te springen om zelf CO_2 te gaan afvangen en opslaan, onder andere omdat de CO_2-prijs nog te laag is voor een positieve business case. De overheid wil dit wel graag, omdat zij de doelstellingen van Parijs wil halen. De inschatting vanuit diverse partijen is dat er een bijdrage vanuit het Rijk en de EU nodig zal zijn om eerstvolgende projecten te financieren. Het is alleen nog onduidelijk hoe dit financieringsmechanisme precies in elkaar zit voor projectfinanciering (in ieder geval niet via de SDE+-regeling). Onderzoeksfinanciering is wel al wat duidelijker, bijv. programma ACT, wat door de EU en Europese overheden gefinancierd wordt.		
B.1. Dependence on other actors	Medium/High	8
De hele keten bij CCS-project moet worden betrokken: Industriële hubs, eigenaar transportleiding, overheid, toezichthouder, eigenaar van het opslagveld, onderzoeksinstellingen, omwonenden, gemeentes, etc—gaat om veel actoren en onderlinge afhankelijkheid is groot..		
B.2 Number of actors	Medium	8
Zie B1, veel partijen. Het is niet per se nodig dat heel Nederland akkoord geeft voor een CCS-project en er is geen actief gedrag van individuele huishoudens nodig.		
B.3 Types of actors involved	High	8
Het doel CO_2-reductie wordt wel gedeeld, maar onderliggende motieven en zorgen van partijen variëren. Bedrijven hebben bijv. o.a. de volgende belangen: goede concurrentiepositie, in Nederland blijven bestaan. De overheid wil de Parijsdoelen halen. NGO's hebben de vraag of CCS investering niet in de plaats komt van investeringen in echt duurzaam.		
B.4 Responsibility unclear	High	7
Dit is al jaren een probleem en groot discussiepunt en diverse partijen wijzen naar elkaar. Barendrecht case: De overheid wilde een CCS-project en schreef een tender uit. Shell won de tender en voerde het project uit en kreeg te maken met de problemen die daarbij ontstonden (geen acceptatie van burgers). De overheid gaf volgens sommige partijen toen niet duidelijk aan dat het project vanuit de wil van de overheid was ontstaan. Er zijn wel protocollen voor de rolverdeling tussen verschillende partijen, en protocollen voor wie wat wanneer aanpakt dient te worden, alleen pakken deze soms ongelukkig uit. Bijv. bewoners moeten geïnformeerd worden op tijdstip x over onderwerp y, maar dat is dan soms nadat de beslissing is genomen dat een project er komt, of juist op een te vroeg tijdstip wanneer de		

details over een project nog niet bekend zijn. Er moeten onder andere nog besluiten worden genomen over de onderwerpen: Wie is juridisch verantwoordelijk voor het opslagveld en voor hoelang? Moet de overheid of de industrie CCS-projecten trekken? Op projectniveau is er een perceptie vanuit diverse partijen dat de rolverdeling nog niet duidelijk is.		
C.1 Physical embeddedness	Medium/high	7
In industrieel gebied valt een extra infrastructuur waarschijnlijk voor een buitenstaander nauwelijks op, omdat deze ook onder de grond kan lopen. Ondergrondse leidingen kunnen ook gebruikt worden voor CO_2 transport op andere plekken (bijv. OCAP-leiding Rotterdam – Amsterdam voor CCU). Ook zijn er offshore leidingen nodig voor offshore opslag (al kan wellicht gebruik gemaakt worden van bestaande infrastructuur). Als het proces bij een industriële partij moet worden aangepast heeft dit potentieel wel een grote impact.		
C.2 Disturbs regular operation	Medium/high	7
Er is vaak een verandering nodig in het proces in een fabriek, vaak eerst pilots voor groot uitrollen.		
C.3 Technology uncertainty	Medium/High	4
Technologisch weten we eigenlijk bijna alles, dat is geen grote barrière, alleen moeten o.a. de kosten omlaag. Alle elementen zijn bekend maar er is nog geen full-chain project in Nederland en ook de cluster aanpak is relatief nieuw.		
D.1 Outside of thinking scope of actor	Low	3
Niet helemaal nieuw voor industriële partijen, zij weten al jaren dat dit bestaat/een optie is.		
D.2 Frequency of opportunity	High	9
Het is nu toch wel 'do or die' voor CCS in Nederland. Er wordt in de nieuwe strategie (roadmap CCS die in ontwikkeling is, regeerakkoord) gemikt op de industrie. Als je de grote industriële hubs bekijkt in Nederland is er een beperkt aantal opties: denk aan Rotterdam, Tata-steel, Limburg, Noord-Nederland. Er wordt vooral gekeken naar opslag op zee. Het window of opportunity is (politiek gezien ook) beperkt.		
D.3 Requires change in behaviour	Low	4
Geen grote aanpassingen in fabrieken qua gedrag—tenzij het primaire proces ingrijpend wordt veranderd.		

Aanvulling tabel
Over de duidelijkheid van de factoren werd gezegd: 'Ik kan me bij de meeste dingen wel iets voorstellen'.

Missende factoren
'Legal': Onduidelijkheid over wie aansprakelijk is voor bijv. opslag (zit onder B4 deels). Zekerheid is belangrijk, is er als iets ook echt in wetgeving is vastgelegd. Nadat verder gevraagd werd over institutionele barrières en of deze ook echt een belemmering vormden: Er is ook nog geen wettelijk framework voor financiering vanuit Nederland. Verder is het EU-beleid en de CO_2-prijs onzeker. Bedrijven hebben een lange termijn zekerheid nodig omdat zij een lange termijn investering doen, zij zien veranderend beleid wel als barrière. Na vraag over of beleid gezien kan worden als oplossing voor barrières: 'Het is de vraag of de barrières op te lossen zijn met beleid'.

Het is voor de CCS-gemeenschap lastig om dit onderwerp goed op de politieke agenda te houden, 'CCS is geen sexy technologie, niemand gaat ervoor staan, mensen willen hun handen er niet aan branden'. De discussie is nu anders dan ten tijde van Barendrecht, er is voor veel industrieën namelijk nog geen alternatief. Het onderwerp lock-ins is ook belangrijk, omdat veel partijen bang zijn dat er geen andere weg meer is als eenmaal gekozen is voor CCS.

Societal perception and acceptance - omwonenden en algemene media en stakeholders (belangenorganisaties). Is belangrijk, kan CCS maken of breken. Wordt ook door diverse stakeholders als belangrijke randvoorwaarde gezien om achter CCS te gaan staan .

Verbanden
Categorie A en B hangen samen, omtrent de vraag: Wie gaan CCS-projecten trekken en wie betaalt dus? De overheid heeft de Parijse doelstellingen, als het financieel interessant is zou de industrie de CCS projecten zelf oppakken. Categorie B en C hangen samen. Hoeveel is er nodig qua fysieke verandering (bouwen

infrastructuur zorgt voor nieuwe partijen) en in hoeverre wordt CCS als een proven technologie gezien door het publiek? (C3 – B1). Bepalende factoren voor investeringskosten zijn: De aanpassingen die gedaan moeten worden aan fabrieken en in hoeverre bestaande infrastructuur gebruikt worden C1 en A1).

Veranderingen ten opzichte van tien jaar geleden
De maatschappelijke discussie over CCS is deels toch anders dan tien jaar geleden.

De kosten en financiering blijven een moeilijk punt. Doordat CCS nu in het regeerakkoord staat wordt er nu wel gepraat over hoe de financiering geregeld moet worden. De CO_2-prijs is nog steeds op een onvoldoende hoog niveau.

De multi-actor complexity is niet verbeterd deze is misschien nog wel groter geworden. De Barendrecht case heeft de publieke perceptie van CCS geen goed gedaan. Het grootschaliger uitrollen van projecten in industriële clusters waar nu op gefocust wordt, zorgt ook deels voor mee complexiteit omdat er meer partijen bij betrokken zijn. Doordat projecten nu waarschijnlijk in industrieel gebied zullen plaatsvinden is er wellicht wel minder bezwaar van omwonenden.

De fysieke barrières blijven gelijk, al zijn de plannen nu wel grootschaliger (C). Het aantal 'opportunities' (D2) is afgenomen ten opzichte van tien jaar terug.

De aandacht voor onderzoek naar publieke perceptie is in de laatste jaren gegroeid, er werd eerst veelal technisch onderzoek gedaan. Er is nu wel meer ervaring over hoe het publiek op een goede manier betrokken en geïnformeerd kan worden, en ook veel inzicht in het hoe en waarom van publieke perceptie rondom CCS, maar het gebruik en toepassen van deze kennis blijft achter en experts op dit gebied worden veel te laat betrokken en geconsulteerd. Het lerend vermogen is klein op dit gebied (er wordt niet actief geleerd van vorige projecten). Er bestaan nu evidence-based aanpakken en er zijn voldoende experts op dit gebied om een goede aanpak op te zetten.

Maatregelen
- Onderzoeksfinanciering is beschikbaar via ACT (EU/NL) om meer inzicht te krijgen in barrières of deze te verlagen (technisch en sociaal-wetenschappelijk) (B + C)
- Er is EU financiering beschikbaar voor demonstratieprojecten (A3)
- Er is een window of opportunity voor CCS omdat dit nu in het regeerakkoord staat, de urgentie voor het halen van de Parijse doelstellingen groter wordt en vanwege de rechtszaak van Urgenda tegen de overheid. Ook is er een urgentie vanuit geopolitiek oogpunt voor een zekerheid voor energievoorziening. De kosten van niets doen beginnen te problematisch te worden. (D2)
- Technologische ontwikkelingen zorgen voor kostenverlagingen (C3 en A1)

Interview Onno Tillema
Carbon Capture Storage - 21-2-2018 – Schiedam
Managing Director Maasvlakte CCS-project ROAD vanuit ENGIE sinds 2010

Factor	Score	Importance
A.1 Investment cost required	High	8
Zeer hoge investeringskosten, ongeveer een half miljard voor afvang en opslag van 1.1 Mton CO_2/y voor het ROAD-project geïnvesteerd door Uniper (voorheen Eon) en ENGIE (voorheen GDF-Suez) en Europese en Nederlandse subsidies. Kosten voor offshore opslag zijn hoger dan voor onshore opslag.		
A.2 Expected pay-back time at 0 euro/ton	High	8
Zeer afhankelijk van de CO_2-prijs. Deze was bij aanvang van het ROAD-project ca 35 euro/ton, toen een aantal jaren ca 5 euro/ton en nu langzaam opgeklommen tot rond 10 euro/ton door Europese maatregelen. Dit zorgt voor een enorm gat in de opbrengsten (ca 30 miljoen per jaar). In Noorwegen is voor offshore een CO_2-prijs van ca 55 euro/ton afgesproken, wat in Noorwegen zorgt voor een business case voor CCS.		
A.3 Difficulty in financing investment	High	8
Zeer moeilijk door hoge investeringskosten en het ontbreken van een business case. Het ROAD-project heeft financiering van de twee energie bedrijven, de EU en de Nederlandse overheid om de grootschalige demonstratie te realiseren		

B.1. Dependence on other actors	High	10
Grote afhankelijkheid door ontbreken van (internationale/nationale) wetgeving, financiering en ingewikkelde vergunningstrajecten van overheden. NGO's kunnen vergunningsprocedures sterk vertragen. Voor aanvullende financieringsvormen vanuit de EU is een samenwerking en support van meerdere lidstaten nodig (NER, Eranet en H2020 van bv Duitsland, Noorwegen of Engeland), ook veroorzaken Brexit-besprekingen onzekerheid. De afhankelijkheid van publieke/politieke partijen kan ook een belemmerende factor zijn. Omdat CCS vaak als controversieel gezien wordt vanwege de link met fossiele brandstoffen, ligt besluitvorming gevoelig vanaf ongeveer een jaar voor nationale verkiezingen. De infrastructuur moet aangelegd en beheerd worden door een partij, de opslag moet weer beheerd worden door een operator.		
B.2 Number of actors	Low	5
In een industrieel cluster is het aantal partijen redelijk beperkt.		
B.3 Types of actors involved	Medium	6
De EU en de Nederlandse overheid staan achter CCS, door bv het verstrekken subsidies. Sommige NGO's zijn niet voor CCS omdat dit gezien kan worden als een verlenging van het gebruik van fossiele energie. Er is met de huidige ETS prijs geen prikkel en geen business case voor bedrijven, zij voeren een CCS project dan ook alleen uit als voldoende middelen beschikbaar gesteld worden en langdurige zekerheden geboden worden die hun investeringen justificeren.		
B.4 Responsibility unclear	High	10
Onduidelijkheid bestaat er met name over de verantwoordelijkheden met betrekking tot opslag van CO2. Van wie is de CO2, tot welke maatregelen wordt je verplicht en hoe lang blijf je hier verantwoordelijk voor. Private partijen kunnen nooit een oneindige verantwoordelijkheid nemen, dit kunnen alleen overheden dragen daar zij ook de voorwaarden stellen. Andere belangrijke vragen zijn: 'Wie betaalt het? Wat is de waarde van opgeslagen CO2 (nu en in de toekomst)? Wie is de klant voor CCS?'		
C.1 Physical embeddedness	Medium	4
Er is een nieuwe infrastructuur nodig voor het transport. Ook het gebruik van lege (offshore/onshore) gasvelden zorgt niet voor veel fysieke veranderingen. Als een fabriek moet worden aangepast om CO2 af te vangen vergt dit wel een aantal aanpassingen eea afhankelijk van de betreffende installatie.		
C.2 Disturbs regular operation	Low	4
Geen significante impact op de reguliere productie van een centrale. In een leeg geproduceerd gasveld wordt de andere kant op gepompt.		
C.3 Technology uncertainty	Low	4
Technologisch geen belemmeringen, in Noorwegen wordt al tientallen jaren CO2 ondergronds opgeslagen en het proces van afscheiden van CO2 door verschillende technieken vele jaren succesvol gedemonstreerd		
D.1 Outside of thinking scope of actor	High	6
Er is nog geen grootschalig CCS-project tot uitvoering gekomen in Nederland maar ook niet in Europa. Het is verre van de dagdagelijkse gang van zaken in de industrie, niet elke industrie heeft de zelfde opslag mogelijkheden en CCS werkt kosten verhogend.		
D.2 Frequency of opportunity	High	10
Zeer beperkt. In Nederland kan transport en opslag alleen door overheidspartijen worden gedragen omdat deze investeringen groot en langjarig zijn en bedrijven niet zo'n langjarige horizon hebben (er wordt nu onderzocht of EBN en GasUnie dit kunnen doen, beide 100% staatseigendom). Ook komen alleen grote CO2 emitters in aanmerking omdat de baten de kosten niet kunnen verantwoorden. Dit omdat er een lange verantwoordelijkheid voor veiligheid is, zeer grote investeringen met een onvoorspelbare terugverdientijd en ingewikkelde vergunningen aan te pas komen. Het is niet realistisch dat zelfs middelgrote private partijen deze risico's kunnen of willen dragen.		
D.3 Requires change in behaviour	Low	4
Er zullen enkele nieuwe handelingen bijkomen als een CCS-project van de grond komt; afvang in fabriek beheer infrastructuur en beheer van opslag		

Aanvulling tabel
De rode draad in het verhaal van het ROAD-project is de grote afhankelijkheid van politieke besluitvorming. "Energie is politiek" kwam hierbij sterk naar voren. Al een jaar voordat er nationale verkiezingen zijn worden er geen gevoelige beslissingen meer genomen over CCS, wat een vertragende factor is voor realisatie. Ook was bestaande wetgeving gericht op winning en niet op opslag. NGO's kunnen afhankelijk van een toepassing een onvoorspelbaar risico vormen in de realisatie van CCS.

Missende factoren
De verwevenheid van politiek en energie en het feit dat publieke acceptatie zo'n grote rol speelt bij CCS zorgt voor grote barrières. De overheid stelt besluiten uit vanaf een jaar voor verkiezingstijd en geeft op deze manier geen zekerheid aan de investerende partijen. Zij stellen hierdoor hun FID (final investment decision) telkens uit tot er wel voldoende comfort is. Onzekerheid over langjarig politiek draagvlak is hierbij de centrale factor.

Verbanden tussen barrières
- Voor de financiering is er een grote afhankelijkheid van de Nederlandse overheid voor Nederlandse subsidies (A3 – B1) en in geval van Europese subsidies van enkele lidstaten. Ook moet altijd rekening gehouden worden dat subsidies getoetst worden op concurrentie bevoordeling.
- Door de onduidelijkheid van verantwoordelijkheden over bijv. het beheer van het opslagveld en wie welk deel betaalt wordt de investeringsbeslissing niet genomen, omdat er onvoldoende zekerheid is (A1, B4).
- Technische opties kunnen soms gebruikt worden om politiek draagvlak te creëren (leiding doortrekken naar ander land of specifieke locatie of verbinding met (her)gebruikers van CO2) en zo ook evt subsidie te krijgen (A1, B1 met C1).

Veranderingen ten opzichte van tien jaar geleden
In Europa zijn in 2008 zeven projecten gestart in verschillende landen. Deze hadden verschillende configuraties (bijv. precombustion – onshore of postcombustion – offshore etc.). Deze projecten zijn om verschillende redenen gestrand, vaak al in een vroeg stadium, vooral om politieke redenen (DE: afvang in het ene bundesländ, opslag in het andere; Polen: tegenwerking vanuit politiek, energie en politiek zijn daar nog sterk verweven, als CCS gedemonstreerd en bewezen is zou het vervolgens overal toegepast moeten worden wat als risico gezien zou kunnen worden; Italië: kreeg vergunningen voor ombouw bestaande installatie niet tijdig genoeg geregeld; Spanje: positieve FID, maar toen kwam de economische crisis, dus werd de centrale waar afgevangen zou worden niet gebouwd. Het ROAD-project in Rotterdam is hiervan nog het langst overgebleven. Dit is uiteindelijk gestaakt in september 2017, omdat de verkiezingsuitslag onvoldoende vertrouwen gaf voor verdere ontwikkeling.
Ten opzichte van tien jaar geleden staat CCS nu duidelijker op de politieke agenda (regeerakkoord), wel zijn door het ROAD-project alle belemmeringen om tot CCS te komen (ontbreken business-case en onduidelijkheden over verantwoordelijkheid) duidelijk geworden**.**

Maatregelen
- Duidelijkheid scheppen in wie wat betaald voor CCS, wie waar verantwoordelijk is en wie garant staat voor de risico's van de opgeslagen CO2 om toekomstige actoren zekerheid te geven (B4).
- Het vergunningsverleningsproces moet sneller gaan verlopen, wetswijzigingen tijdens het proces moeten niet meer nodig zijn (B1)
- De business case voor CCS moet versterkt worden door zekerheid omtrent inkomsten, bijv. hogere ETS prijs of een minimum CO2-prijs in Nederland; meer financiering vanuit de overheid. Hierbij moet ook op de lange termijn gedacht worden, als een kolencentrale moet sluiten in 2030, is het dan een verantwoorde zet om bij die centrale CO2-afvang te realiseren? (A2)

Interview Suzanne Brunsting

Carbon Capture Storage - 02-03-2018 – Amsterdam

Onderzoeker bij ECN van onder andere CCS (NearCO2, CATO-2, SiteChar) – Hoe kijkt lokale bevolking aan tegen geplande projecten in Europa, onderzoek naar CCS-project in Barendrecht. Organiseren van large group processes en focus conferences op verschillende plekken in Europa.

Factor	Score	Importance
A.1 Investment cost required	High	A 8 B 1
Een project kan alleen van de grond komen met subsidie. Deze was toegezegd in Barendrecht waardoor dit geen grote drempel was. Ook kon gebruik gemaakt worden van de bestaande gasinfrastructuur en een leeg gasveld. Vanuit sociaalwetenschappelijk perspectief geldt hiervoor de vraag: Staan de kosten tegenover de baten van CCS?		
A.2 Expected pay-back time at 0 euro/ton	High	A - B -
Niet van toepassing, omdat CCS nu enkel geld kost. Dit kan anders worden als de CO2-prijs van voldoende niveau is.		
A.3 Difficulty in financing investment	High	A 10 B 8
Er is subsidie nodig voor een project, in Barendrecht was dit 30 miljoen, maar Suzanne Brunsting heeft zelf geen onderzoek gedaan naar dit gedeelte van CCS. Het feit dat de toekenning een jaar later plaatsvond dan gepland geeft wel aan dat ook deze subsidieverstrekking niet zonder slag of stoot tot stand is gekomen.		
B.1. Dependence on other actors	High	A ? B 10
Betrokken partijen waren: Shell, ministerie van Economische Zaken, Ministerie VROM, gemeente Barendrecht (college B&W, gemeenteraad, politieke partijen), DCMR, inwoners van de gemeente Barendrecht,NAM (tot medio 2008). De invloed van actoren is afhankelijk van de culturele context waarin het project plaatsvindt, in Nederland heeft het lokale niveau relatief veel invloed.		
B.2 Number of actors	Low	A 3 B 3
Er is een beperkt aantal organisaties nodig om het project van de grond te laten komen.		
B.3 Types of actors involved	High	A ? B 8
Heel diverse groep van actoren. De gemeenteraad stond er heel anders in dan alle andere projectpartners. De bevolking werd aan het eind van het project gemobiliseerd door de gemeenteraad. Dit is uniek, meestal is het zo dat de gemeente achter het project staat en de bevolking er juist tegen is. De kennisverschillen tussen actoren waren groot. Ook waren de normen en waarden tussen actoren verschillend. Partijen praatten op deze manier langs elkaar heen: de projectpartijen hadden een meer technisch verhaal, wat onderbouwd was door vele onderzoeken. De bewoners/gemeenteraad hadden zorgen die buiten deze onderzoeken vielen, welke niet serieus werden genomen/relevant werden geacht door de projectpartners.		
B.4 Responsibility unclear	Low	A ? B 8
Duidelijke verdeling van verantwoordelijkheden binnen het project. De Rijkscoördinatieregeling die tijdens het project werd ingevoerd zorgde voor een andere verdeling van verantwoordelijkheden. Op zich was die verdeling wel helder, maar er werd tegen toepassing van de regeling in Barendrecht geprotesteerd omdat de gemeente hierdoor buitenspel zou komen te staan		
C.1 Physical embeddedness	Low	A ? B 3
Fysiek is de verandering heel gering. Hierdoor was er verbazing bij de partijen die betrokken waren bij het CCS-project dat er zoveel weerstand kwam, 'what is the big deal?', maar er was bijv. onrust bij bewoners over een CO2-lek. Er konden CO2-meters geplaatst worden, maar deze geven vaak een vals positief wat inwoners onnodig zou alarmeren, dus dit werd uiteindelijk niet gedaan.		
C.2 Disturbs regular operation	Low	A ? B 3
Vrijwel niet. Er hoeven geen huizen tegen de grond of bouwwerken neergezet te worden.		
C.3 Technology uncertainty	Medium	A 8 B 10

Op onderdelen beheersen we de technologie, maar de volledige keten is nog nooit goed getest. Barendrecht was een demonstratieproject, er zijn nog geen voorbeelden van permanente CO2-opslag op land.		
D.1 Outside of thinking scope of actor	Low	A ? B ?
Onderscheid tussen awareness (gehoord hebben van) en knowledge (weten wat het inhoudt). De verantwoordelijke partijen voor het project (Shell, overheid) hadden veel inhoudelijke kennis over CCS (zie score low). Het kennisniveau onder de Nederlandse bevolking was destijds laag, bleek uit een landelijk representatief onderzoek van ECN. Zij zijn niet de partij die over een project beslist uiteindelijk, daarom is vanuit Shell, overheid geredeneerd. Om het lokale publiek voldoende mogelijkheid toegang tot informatie te geven was er een informatiecentrum in het winkelcentrum nabij de woonwijk waar de CO_2 injectie zou gaan plaatsvinden. Ook was er een Taskforce CCS die landelijk de communicatie rondom CCS moest verzorgen.		
D.2 Frequency of opportunity	High	A: 10 B 10
Zeer zelden. Lege velden in Groningen zijn ook geen optie meer in Nederland, omdat dit politiek gevoelig ligt. Ook zijn er nog geen onshoreprojecten gerealiseerd.		
D.3 Requires change in behaviour	Low	A 3 B 3
CCS is bedoeld als transitietechnologie zodat benodigde gedragsaanpassingen geleidelijk kunnen gaan. Juist zonder CO2-opslag moeten mensen op relatief korte termijn radicale levensstijlverandering maken. CCS zou juist de energietransitie faciliteren, omdat er minder halsoverkop industrieën moeten worden omgebouwd en/of we massaal moeten overstappen op andere typen producten. In de publieke opinie lijken consequenties voor eigen gedrag en leefstijl echter niet in ogenschouw te worden genomen. Deze koppeling is ook zeer moeilijk aanschouwelijk te maken voor mensen, omdat men dan behoorlijk wat moet afweten van het energiesysteem.		

Aanvulling tabel
- Het ontbreken van een goed proces van het betrekken van de omgeving bij het CCS-project ontbrak in Barendrecht. Dit was de crux voor de tegenstand vanuit de bewoners en gemeenteraad over dit project (zie B3).
- Geen missende factoren, op hoofdlijnen kon de dynamiek in Barendrecht geschetst worden .
- D1: Moeilijk om aan te geven wie de responsible party is, B2 behoeft extra uitleg.
- Belangrijk om bij gebruik van de scores de context erbij te geven, bijv. B3 verschil in waarden.
- De scores algemeen voor CCS zijn aangegeven met A, de scores voor CCS in Barendrecht met B. Dit maakt nogal een verschil. Zo is in het algemeen financiering een issue, maar deze was in Barendrecht rond. Zo was in Barendrecht de afhankelijkheid van andere stakeholders enorm hoog, maar dat zou niet zo zijn als je dezelfde technologie in de Sahara wil implementeren.

Verbanden tussen barrières
- Door de Rijkscoordinatieregeling worden de verantwoordelijkheden aangepast ten opzichte van de regels die normaal gesproken gelden. Dit zorgt voor een andere afhankelijkheid tussen actoren en andere verantwoordelijkheden (B1 & B4).

Veranderingen ten opzichte van tien jaar geleden
Ik betwijfel of de situatie nu veel veranderd is rondom CCS ten opzichte van tijdens het Barendrecht project. Om iets te zeggen over CCS-onshore maak ik een analogie met wind op land, omdat er nu geen CCS-onshoreprojecten zijn. Tegen wind op land zijn op dit moment hevige protesten. Deze projecten hebben namelijk impact op iemands directe leefomgeving, zonder dat deze persoon daar zelf invloed op kan hebben of daar direct de baten van ondervindt. Hieraan linkt het concept 'place attachment', wat inhoudt dat mensen gehecht zijn aan hun leefomgeving hoe deze is. Dit gaat ook om plekken die voor buitenstaanders lelijk of niet essentieel lijken (bijv. een veldje achteraf op een industrieterrein waar veel mensen hun hondenuitlaatrondje hebben). Dit concept linkt aan C1, omdat dit gaat over wat mensen fysiek zien van het project.

Maatregelen
- Door het invoeren van een CO2-prijs kan er een business case gemaakt worden. Dit zou ook in Nederland kunnen worden ingevoerd als daar politiek draagvlak voor is (A2).

- Analogie met wind onshore: Certificaten om rendement te kunnen ontvangen van een windpark nabij kunnen worden aangeboden aan omwonenden. Als de prijzen van de certificaten te hoog zijn is deze compensatieregeling niet inclusief. (B1)
- De inwoners baten geven van het project door bijv. een compensatieregeling. Daar moet wel grond voor zijn, bijv. compensatieregeling voor waardedaling woning (als dit van toepassing is). Voor een compensatieregeling moet een grondslag zijn. (B1).

Interview Jeroen Bruijn en Joëlle Rekers

Carbon Capture Storage - 14-3-2018 – Den Haag
Junior en seniorbeleidsmedewerkers van het Ministerie van Economische Zaken en Klimaat op het gebied van Carbon Capture Storage

Factor	Score	Importance
A.1 Investment cost required	High	5
CCS is een kaptiaalintensieve techniek. Een project met afvang, transportleiding en opslaglocatie kost al gauw een paar honderd miljoen euro.		
A.2 Expected pay-back time at 0 euro/ton	High	9
Bij CCS is nu nog geen of een hele lange terugverdientijd. Deze hangt sterk af van de CO2-prijs. Deze terugverdientijd kan verschillend zijn voor de onderdelen van de CCS-keten. Deze onderdelen kunnen ook door verschillende partijen worden gefinancierd.		
A.3 Difficulty in financing investment	High	7
Door de lange terugverdientijd, nemen bedrijven niet uit zichzelf de gehele investering op zich. De Europese Investeringsbank is geïnteresseerd in het financieren van CCS-projecten. Zij vinden lange terugverdientijden ook acceptabel, maar moeten wel uitzicht hebben op het terugverdienen van de investering. Er is op dit moment geen Europees of Nederlands subsidiebeleid voor CCS-projecten.		
B.1. Dependence on other actors	High	8
Er wordt tegenwoordig gekeken naar projecten met meerdere afvangers van CO2. Er is dan een transportnetwerk in plaats van één leiding nodig. Hierdoor ontstaat een coördinatieprobleem, wie gaat deze leiding aanleggen? Een publieke of private partij? Partijen hebben verschillende expertises, voor de verschillende systeemonderdelen (afvang, transport opslag) kan het zo zijn dat verschillende partijen hierin de hoofdrol nemen vanwege verschillende expertises. De overheid is nodig voor het afgeven van vergunningen en een financiële tegemoetkoming. Timing is belangrijk, op meerdere momenten in de vorming van beleid rond CCS moet er politiek draagvlak zijn (e.g. beslissen over een subsidieschema).		
B.2 Number of actors	Low	5
Het is redelijk beperkt hoeveel partijen betrokken zijn bij een CCS-project (zie B1). De Tweede Kamer/ maatschappij wordt hierbij wel als één partij gezien.		
B.3 Types of actors involved	Medium	6
Betrokken actoren hebben verschillende belangen bij CCS. De overheid (klimaatdoelstellingen halen incl. behoud concurrentiepositie), industrie (tegen zo laag mogelijke kosten doelstellingen halen), maatschappij (veilig, maar wil niet dat 'geld naar de fossiele industrie gaat', maar ook een energietransitie tegen niet al te hoge kosten), NGO's ('vervuiler betaalt'). In deze belangen zijn ook tegenstellingen te vinden.		
B.4 Responsibility unclear	Medium	8
Verschillende partijen kijken naar de Rijksoverheid die de klimaatdoelen heeft vastgesteld. De industrie wacht op subsidies om projecten uit te voeren. Dit strookt niet met het 'vervuiler betaalt' principe dat ook door een aantal partijen wordt benoemd. Partijen kijken naar de overheid om bepaalde randvoorwaarden te scheppen voor het van de grond komen van projecten.		
C.1 Physical embeddedness	Medium	6
Voor een afvanginstallatie is een vrij groot gebouw nodig, evenals voor een compressorstation. Dit valt visueel niet op in een industrieel gebied. Een buisleiding kan al in een bestaand buisleidingtracé worden gelegd.		
C.2 Disturbs regular operation	Medium	6

Dit valt mee. Bij de ingebruikname van de afvanginstallatie in Canada had deze installatie nog wat opstartproblemen.		
C.3 Technology uncertainty	Medium	6
De verschillende onderdelen van de CCS-keten zijn bewezen (opslag, transport, afvang). Afvang heeft nog iets meer onzekerheid, omdat het nog niet in veel verschillende industriële takken is toegepast. Over het koppelen van de verschillende onderdelen is wel nog wat technische onzekerheid. Er is op dit punt nog ruimte in de leercurve.		
D.1 Outside of thinking scope of actor	Medium	6
De optie van CCS voor CO2-reductie is bekend bij de grote industrie. Een aantal bedrijven overweegt nu deze optie te implementeren. De kennis van de industrie mbt wat er komt kijken bij het implementeren van CCS en of het passend is bij het bedrijf kan zich nog verder ontwikkelen: Nog niet veel bedrijven hebben uitgebreid onderzocht hoe zij CCS kunnen toepassen.		
D.2 Frequency of opportunity	Medium	6
Het vergunningstraject kan op zich ieder moment gestart worden. Als er een tijdelijke subsidie beschikbaar is, kan dit partijen ook aanzetten tot het starten met dit traject. Als deze te laat zijn kan het ook dat de mogelijkheden voor hen afnemen, omdat zij subsidie nodig hebben voor het project.		
D.3 Requires change in behaviour	Medium	6
In de operationele sfeer zullen er wel enige kleine veranderingen zijn, maar het is niet zo dat de bedrijfsvoering van het bedrijf geheel anders wordt.		

Aanvulling tabel
- De volgende uitspraken werden gedaan tijdens het praten over de tabel: 'Het was soms lastig om te kiezen tussen bijv. few en many.'. 'Voor CCS geeft de methode de belangrijkste bottlenecks aan.' 'Het is lastig om de factoren los van elkaar te trekken, er is veel samenhang' .

Missende factoren
- De onduidelijkheid over coördinatie: Omdat verschillende partijen verschillende onderdelen van de CCS-keten onder hun hoede nemen is er geen duidelijke coördinerende partij welke zorgt dat alle neuzen dezelfde kant op staan op de belangrijke beslismomenten.
- Politiek draagvlak is nodig voor het starten van een nieuw CCS-project. Op de ambitie die uitgesproken is in het regeerakkoord kwam een reactie vanuit de maatschappij. Bedrijven wachten af tot het eerste demonstratieproject geweest is.

Verbanden
- De lange of afwezige terugverdientijd zorgt ervoor dat partijen meer moeite hebben met het investeren van grote bedragen. Ook is het überhaupt lastiger om hierdoor investeerders te vinden. (A1, A3 met A2).
- Als de terugverdientijd van een investering lager is zijn partijen ook eerder geneigd om de verantwoordelijkheid voor een project op zich te nemen, dit gebeurt minder snel bij lange terugverdientijden (A2, B4).
- De afhankelijkheid van partijen en de duidelijkheid van verantwoordelijkheden hangen sterk met elkaar samen. Bij een duidelijke verdeling van verantwoordelijkheden is de afhankelijkheid ook kleiner/vloeit hieruit minder onzekerheid (B1, B4).
- Als er een business case is voor CCS, komt deze optie ook meer in het vizier van industriële partijen (A2, D1).

Veranderingen ten opzichte van tien jaar geleden
Ten opzichte van tien jaar is er weinig veranderd aan de barrières in categorie A en C. De noodzaak voor het nemen van maatregelen op het gebied van de reductie van CO2-uitstoot is hoger geworden, ook bij NGO's is dit nu duidelijker. Hierdoor is de optie CCS wel bekender geworden bij industriële partijen (D1). Ten opzichte van tien jaar geleden wordt er nu meer gekeken naar industriële hubs en netwerken. Doordat er dan meerdere partijen op één netwerk moeten worden aangesloten, zorgt dit voor een hogere 'multi-actor complexity'. Vanwege de keuze om nu naar opslag op zee te kijken is minder weerstand te verwachten vanuit de maatschappij.

Maatregelen

- Er zijn allerhande mogelijkheden om barrières met beleid te beïnvloeden. Hierin moet gekozen worden welk soort beleid passend is (wet- en regelgeving, stimulerende maatregelen, prijsprikkels). Neemt de overheid de hoofdrol, wordt deze bij private partijen gelegd of worden deze gestimuleerd via prijsprikkels? In hoeverre wordt CCS uit publiek geld gefinancierd? Is dit eenmalig of op de lange termijn?
- Beleid gericht op innovatie om nieuwe technieken te ontwikkelen en de kosten te verlagen (C3, A)
- Onderzoek en innovatie om techniek verder te ontwikkelen en kosten te verlagen (C3, A)
- Een demonstratieproject van de gehele keten realiseren (C3).
- Een langetermijnvisie vanuit de overheid ontwikkelen op het gebied van CCS.
- Kennisuitwisseling met andere landen (C3).

Interview Saeda Moorman

Biobrandstoffen - 22-2-2018 – Den Haag

Onderzoeker duurzaam mobiliteitsbeleid en verkeersbrandstoffen – Kennisinstituut voor Mobiliteit

Factor	Score	Importance
A.1 Investment cost required	Medium/High	
Productie van biobrandstoffen opschalen, auto aanpassen (als je wil uitgaan van de huidige auto; je kunt ook het natuurlijke vervangingsmoment van de auto afwachten en dan een auto kopen die meteen al geschikt is voor plantaardige olie). Biobrandstoffen zijn relatief duurder dan benzine, maar over PPO (puur plantaardige olie) hoeft geen accijns te worden betaald. Investeringen voor de landbouw kunnen hoog zijn als zij omschakelen op een ander gewas.		
A.2 Expected pay-back time at 0 euro/ton	?	
Ombouw van het voertuig kan evt. terugverdiend worden door te kijken naar het verschil in brandstofprijs tussen PPO en benzine/diesel, kosten van de ombouw en rijgedrag.		
A.3 Difficulty in financing investment	Low	
Je kunt waarschijnlijk niet naar de bank voor een lening om je auto om te bouwen. De investering is betrekkelijk klein waardoor verschillende financierders niet nodig zijn.		
B.1. Dependence on other actors	Low/medium	
Bij PPO moet je zelf voor je brandstof zorgen, dat kun je niet ergens tanken. Het bedrijf dat je motor ombouwt als je deze moet laten ombouwen. Afhankelijk van de landbouwsector voor grondstof, de plantaardige olie moet gemaakt worden in een fabriek.		
B.2 Number of actors	High	
Helemaal aan het einde van de keten, beslissingen moeten op individueel niveau genomen. Elk transportmiddel moet geschikt gemaakt worden.		
B.3 Types of actors involved	Low	
De landbouwsector wil graag haar grond gebruiken om iets op te verbouwen, deze zijn dus vóór biobrandstof. In Europa kan er ook afscherming van de markt plaatsvinden, er kan in Europa biobrandstof geproduceerd worden, dit is in het belang van de eigen Europese landbouwsector. Verschillende meningen over of biobrandstof wel echt CO_2-uitstoot reduceert (zie verder in verslag).		
B.4 Responsibility unclear	High	
In dit geval is het de gebruiker nog niet verplicht dat deze moet kiezen voor biobrandstof, er is nog geen verantwoordelijkheid belegt. Brandstofproducenten en autofabrikanten moeten al voldoen aan de eisen uit de FQD en RED vanuit Europa.		
C.1 Physical embeddedness	High	
Als iedereen op PPO gaat rijden, hoeveel landbouwgrond zou je dan nodig hebben? Een andere motor zou nodig zijn in de auto. Grote verschillen tussen de schaalniveaus.		
C.2 Disturbs regular operation	High	
Het ombouwen kan misschien zorgen voor wat gedoe. Autofabrikanten moeten hun productieprocessen aanpassen en alleen nog auto's produceren die op PPO kunnen rijden. Landbouwers moeten hun proces veranderen. Het voedsel dat eerst werd verbouwd op de landbouwgrond moet ergens anders worden verbouwd. Grote stromen/verschuivingen komen zo op gang.		
C.3 Technology uncertainty	Low	
We weten dat het kan, het proces is bewezen.		
D.1 Outside of thinking scope of actor	High	
Het zou kunnen dat landbouwers erop gefocust zijn om bijv. mais te verbouwen en geen koolzaad. De ene landbouwer is waarschijnlijk flexibeler om om te schakelen dan de andere.		
D.2 Frequency of opportunity	Medium	
Ongeveer om de twaalf jaar dat je een nieuwe auto aanschaft. Een omschakeling van gewas zal niet bij alle landbouwers vaak voorkomen (zie ook D.1).		

D.3 Requires change in behaviour	High	
In het begin zou je zelf olie uit de supermarkt in je auto moeten gieten, maar naar verloop van tijd komen er waarschijnlijk tankstations. Voor de landbouwer is het een behoorlijke verandering als die een ander gewas moet verbouwen (zie ook D.1).		

Aanvulling op tabel
Dit onderwerp leent zich vrij moeilijk voor het eenduidig invullen van de tabel. Eerst is begonnen met kijken vanuit een groep consumenten die op biobrandstof gaat rijden en welke barrières die ziet voor de overgang. Daarna is meer gepraat over wat voor impact een overgang van een grotere groep heeft op de hele keten (boeren die andere gewassen moeten verbouwen, nieuwe industrie, weggaan van huidige fossiele brandstofproducenten (m.n. benzine, diesel)). Ook is gekozen om de antwoorden te geven voor het overgaan op de biobrandstof PPO. De verschillende schalen die spelen bij deze case maken het moeilijk om een keuze voor low – medium of high te maken en rapportcijfers toe te kennen.

De opmerking werd gemaakt dat B4 op verschillende manieren uitgelegd kan worden. Het ligt eraan hoe de maatregel wordt ingevoerd (met welk beleid). In dit geval wordt gekeken vanuit een grote groep burgers die overgaan op biobrandstoffen en wat hen tegenhoudt. Op dit moment is het niet duidelijk dat zij deze verantwoordelijkheid hebben om over te stappen en of de overheid die nadrukkelijk neemt door echte verplichtingen te stellen aan producenten. De verantwoordelijkheid is dus onduidelijk.

Missende barrières
- Publieke opinie: Rond het onderwerp biobrandstoffen is er zowel op politiek als wetenschappelijk gebied nog steeds een discussie gaande of dit wel of niet zorgt voor minder CO_2-uitstoot als biobrandstoffen over de gehele keten worden bekeken. Als je bijv. een bos kapt is er niet een dag later een nieuw bos, braakliggende grond die omgewoeld wordt kan ook CO_2 uitstoten en landbouwvoertuigen gebruiken zelf ook brandstof. Vragen als: zorgt grootschalige productie van biobrandstoffen niet ergens anders in de keten voor problemen (concurrentie om landbouwgrond) spelen rond dit onderwerp. Deze onzekerheid maakt banken huiverig om te investeren in biobrandstofprojecten, omdat de publieke/politieke opinie/perceptie over dit onderwerp kan omslaan en je dan eventueel investeert in een doodlopende route. (Publieke opinie – A3).
- Sterke gevestigde belangen uit de fossiele brandstofsector en autofabrikanten. De productie van biobrandstoffen zou namelijk gaan plaatsvinden in de landbouwsector in plaats van de fossiele brandstofsector. Autofabrikanten moeten hun automotoren aanpassen voor rijden op plantaardige olie. Deze sterke gevestigde belangen gaan tegenwerken bij grootschalige overgang naar biobrandstoffen/plantaardige olie. De overheid moet een sterke rol nemen om een lelijk jong eendje 'nieuwe technologie' te beschermen, zodat deze tot zwaan kan uitgroeien. Er zitten in het algemeen nog veel imperfecties in nieuwe technologieën dus er is tijd voor nodig om deze te verbeteren.
- Padafhankelijkheid is hieraan deels gerelateerd: Er is voor de transportsector een uitgebreid systeem van tankstations, raffinaderijen en oliewinning en het is moeilijk om een ander pad op te gaan. Hierbij is van belang hoeveel het nieuwe systeem afwijkt van het huidige systeem (B1, B3, C1).

Verbanden tussen factoren
Categorie C (landbouw anders en fabrieken ombouwen) linkt aan gevestigde belangen die heel sterk zijn van deze groep. (C1 met B1, B3).

Veranderingen ten opzichte van tien jaar geleden
De ontwikkeling rond geavanceerde biobrandstoffen is stil komen te liggen doordat er tien jaar geleden nog veel optimistischer over werd gepraat. Investeringen zijn teruggelopen omdat banken ook huiverig zijn voor de discussie over biomassa. De politieke omgeving is veranderd wat onzekerheid brengt.

Maatregelen
Er is nu geen politieke wil om iedereen op biobrandstoffen te laten rijden, dus vanuit Nederland is niet veel wetgeving op dit gebied. De meeste sturing komt vanuit de EU, hiervoor is ook een sterke lobby geweest vanuit de landbouwsector (oa Frankrijk) in het kader van de werkgelegenheid die opschaling oplevert in deze sector. EU-wetgeving voor biobrandstoffen staat in de RED (renewable energy directive, biobrandstof bijmengen bij benzine, eisen aan duurzame productie biobranstof) en FQD, fuel quality directive = producenten moeten zorgen dat ze binnen x jaar tijd een 6%-reductie in hun CO2-uitstoot krijgen, focus op CO_2-inhoud van de brandstof).

In de transportsector kan op verschillende manieren gestuurd worden op CO_2-reductie (Kennisinstituut voor Mobiliteit, 2013)[4]. De knoppen waaraan je kan draaien zijn de volgende: CO2-uitstoot transportsector = km * efficiëntie * brandstof
- Direct sturen op CO_2 (bijv. CO_2-markt, CO_2-heffing verkeer)
- Aantal gereden km verlagen [km] (minder rijden, bijv. kilometerheffing)
- Efficiëntie van de motor [J/km] (motorefficiency, stroomlijn auto, normen over efficiency EU, Nederlands niveau fiscale voordelen, bijv. lage bijtelling voor efficiënte auto's, nu alleen nog voordelen voor emissieloze auto's)
- Brandstof [CO_2/J] (bijv. elektrische auto, H2-auto, biobrandstoffen)

Interview Eric van den Heuvel
Biobrandstoffen - 01-03-2018 – Den Haag
Voorzitten Platform Duurzame Biobrandstoffen vanuit GearUp, contactpunt voor overheid met partijen uit de gehele biobrandstoffenketen

Factor	Score	Importance
A.1 Investment cost required	Medium	6
Dit verschilt per optie, in sommige gevallen zijn er geen investeringskosten voor de consument (hernieuwbare diesel). Ombouw van de motor bij benzineauto's brengt wat kosten met zich mee. In de productieketen voor biobrandstoffen zijn wel investeringen nodig.		
A.2 Expected pay-back time at 0 euro/ton	Medium	6
De kosten van de productie-installaties voor biobrandstoffen zijn redelijke hoog. De terugverdientijd met het huidige systeem van belastingheffing op brandstoffen zal lang zijn. Als CO_2-intensiteit van brandstoffen belast gaat worden, zal de terugverdientijd teruglopen.		
A.3 Difficulty in financing investment	High	9
Voor de ontwikkeling van biobrandstoffen is langdurige overheidssteun nodig, tot en met de uitrol van brandstoffen op de markt. Ook is uitgesproken steun voor biobrandstoffen vanuit de overheid belangrijk voor partijen in de keten, omdat dit hen investeringszekerheid biedt.		
B.1. Dependence on other actors	High	9
Het is een ketenuitdaging om biobrandstoffen op grote schaal te produceren, een fijnmazige samenwerking tussen partijen in de keten is hiervoor essentieel. Ook uitgesproken steun van de overheid is belangrijk. Het is nog onduidelijk hoe de lusten en lasten over de keten worden verdeeld. Betrokken actoren zijn oa: huishoudens, netwerk van tankstations, verschillende brandstofmerken die biobrandstoffen aanbieden, productiefaciliteiten.		
B.2 Number of actors	High	7
Veel actoren, nu 8,2 miljoen auto's in Nederland die je kennis wilt geven over biobrandstoffen.		
B.3 Types of actors involved	High	7
Diversiteit aan actoren is kenmerkend voor biobrandstoffen, zowel het type auto dat de huishoudens hebben als de wensen die zij hebben mbt de brandstof: 'een gezondheidsfreak wil niet rijden op frituurvet', 'geen dierlijke vetten in mijn auto want ik ben vegetariër', low-cost brandstof, hoge		

[4] Kennisinstituut voor Mobiliteit, 2013. *Beleidsopties voor vermindering van de CO_2-uitstoot van het wegverkeer. Naar duurzaam wegverkeer in 2050, deel 2.* Verkregen van: https://www.kimnet.nl/publicaties/rapporten/2013/10/15/beleidsopties-voor-vermindering-van-de-co2-uitstoot-van-het-wegverkeer

prestatiebrandstof. De keten moet dit diverse aanbod mogelijk maken, omdat de klant met pure biobrandstof eisen gaat stellen aan het product. Dit botst met hoe de sector nu georganiseerd is, namelijk op de levering van bulkproducten.		
B.4 Responsibility unclear	High	8
Het is nu nog onduidelijk hoe de lusten en lasten verdeeld worden over de keten bij een grootschalige adoptie van biobrandstoffen. Nu betaalt de brandstofgebruiker ervoor (verhoogde brandstofprijs door bijmenging biobrandstoffen). Sommige consumenten zijn bereid om meer te betalen om CO_2-uitstoot te vermijden (zoals mensen bereid zijn om de meerprijs voor biologische producten te betalen).		
C.1 Physical embeddedness	Medium	6
Dit verschilt per optie (zie onder tabel). Soms zijn aanpassingen nodig in de brandstofinfrastructuur en nieuwe pompen op tankstations. In benzineauto's zijn motoraanpassingen nodig.		
C.2 Disturbs regular operation	Medium	6
Beperkt, er moet nog steeds brandstof in de pomp gedaan worden.		
C.3 Technology uncertainty	Low/Medium	6
Veel systemen bestaan al en zijn bewezen.		
D.1 Outside of thinking scope of actor	High	8
De eindgebruiker is zich niet bewust van de bijmenging die nu plaatsvindt en ook niet van de mogelijkheid tot actie (kies groene pomp op het tankstation). In de productieketen is de optie wel bekend, al weet men niet precies hoe deze vorm te geven. Men denkt dit te doen op eenzelfde manier als het huidige systeem werkt, maar Eric van den Heuvel geeft aan dat biobrandstof niet als bulkproduct wordt gezien in tegenstelling tot benzine/diesel.		
D.2 Frequency of opportunity	Low	8
Een eindgebruiker waarvan de auto niet hoeft te worden aangepast heeft een keuzemoment bij iedere tankbeurt. Voor een GroenGas auto moet de keuze gemaakt worden bij aanschaf van een nieuwe auto. Ombouw is altijd mogelijk.		
D.3 Requires change in behaviour	Low	8
De consument moet nog steeds naar het tankstation, het gedrag verandert niet.		

Aanvulling tabel
- Voor biobrandstoffen zijn er vier hoofdopties welke een verschillend karakter hebben:
* Bijmengen van biobrandstoffen bij benzine en diesel. Hiervoor is nu een verplichting vanuit de EU. De meerprijs wordt afgewenteld op de consument. De huidige infrastructuur en automotoren kunnen benzine normaal gebruiken tot ongeveer 10% bijgemengde biobrandstoffen.
* Auto's laten rijden op E85 (85% bijgemengde biobrandstoffen). Hiervoor moeten er aanpassingen aan de auto gemaakt worden bij benzineauto's.
* Voor de dieselmarkt bestaat hernieuwbaar synthetische diesel. Deze biodiesel kan zonder aanpassingen in een dieselauto gebruikt worden.
* Het is daarnaast ook mogelijk te rijden op GroenGas (bio-CNG). Er is in Nederland een dekkend netwerk van tankstations waar dit verkrijgbaar is.
- Als achtergrond over het huidige Nederlandse beleid: Focus op elektrisch rijden, daar waar dit mogelijk is liever geen andere technologieën. Er zijn nu 20.000 elektrische auto's van 8,2 miljoen in totaal. Dit zijn vooral leaseauto's, voor veel consumenten zijn elektrische auto's te duur. Het doel is om 2030 alleen nog elektrische auto's te verkopen. In de tussentijd blijven verbrandingsmotoren nog een aantal jaren dominant. De vraag is dus, hoe kan de CO_2-intensiteit van vloeibare brandstoffen omlaag worden gebracht?

Missende factoren
Er werden geen missende factoren genoemd en de factoren hoefden niet verder toegelicht te worden.

Verbanden
- Een consument kan bij de pomp steeds de keuze maken tussen bijv. synthetische diesel en reguliere diesel. De verschillen in literprijs kunnen deze keuze beïnvloeden (D2, A1).
- De subsidie van de overheid tot uitrol in de markt in combinatie met uitgesproken steun voor een nieuwe technologie is belangrijk om een nieuwe technologie tot bloei te laten komen (A3, B1)

- De overheid is heel bepalend in het actorenveld. Als deze zich uitspreekt voor een optie en zekerheid biedt, wordt er actie ondernemen (B1, B4).

Veranderingen ten opzichte van tien jaar geleden
Tien jaar geleden kwam op tafel dat er onverwachte bijeffecten zijn van het gebruik van biobrandstoffen. Dat heeft ervoor gezorgd dat de zoektocht naar welke biobrandstoffen een rol moeten spelen nu gerichter is geworden. Welke grondstoffen kunnen we het beste gebruiken om biobrandstoffen te maken? Hiervan kennen we nu de ontwerpparameters beter dan tien jaar geleden. Dit probleem is nu beter onderzocht, maar nog meer onderzoek is nodig.
- Het beeld bij het publiek is nu 'biobrandstoffen zijn slecht', bij deskundigen 'we kennen nu de parameters om goede brandstoffen te kiezen'. De eerste ontwikkelingen van nieuwe producten verlopen rommelig, er moet nog uitgezocht worden wat werkt en wat niet. He is niet goed om technologieën in dit zoekproces snel af te serveren. Het slechte beeld van het publiek moet aangepast worden aan de opgedane kennis: de betere ontwerpparameters voor geschikte biobrandstoffen. Veel mensen zijn zich er ook niet van bewust dat er nu ook biobrandstoffen worden bijgemengd. De urgentie om het klimaatprobleem aan te pakken is nu wel groter geworden door het akkoord van Parijs.

Maatregelen
- Het platform duurzame biobrandstoffen zorgt ervoor dat er één aanspreekpunt is voor de overheid met de gehele keten. Zo kan er meer langetermijnoverleg worden gevoerd met de overheid en kan er gewerkt worden aan een communicatiestrategie rondom biobrandstoffen om dit bekender te maken bij de burger. De leden van het platform delen de ambitie om CO_2-uitstoot terug te dringen en een impuls te geven aan de biobased economy in Nederland. Het platform stimuleert samenwerking in de keten, kennisopbouw en het opzetten van nieuwe projecten. Zo is er goede informatie bekend bij de overheid als zij een besluit over transportbeleid gaan nemen (B1).
- Om alle huishoudens de optie te geven over te stappen op biobrandstoffen is dus een gemêleerd programma nodig, waarbij advies op maat wordt gegeven.
* Voor synthetische diesel zou er een vergoeding kunnen komen vanwege de CO_2-besparing die dit oplevert. Een andere optie is het belasten van CO_2-intensiteit van brandstoffen, zodat deze duurdere diesel er beter uitkomt ten opzichte van fossiele brandstoffen (A2).
* Voor GroenGas bijv. een Garantie van Oorsprong-systeem voor gas uit Europa (zoals bij groene elektriciteit bestaat), zodat er voldoende GroenGas beschikbaar is. Om op GroenGas te rijden is het wel nodig om een GroenGasauto aan te schaffen (A1).
* Ombouwkit voor benzineauto's zodat deze kunnen rijden op E85 brandstof. Om ombouw te stimuleren kan een programma opgezet worden om ombouwers te ondersteunen. (A). Waarschijnlijk is ombouw vooral gefocust op tweedehandsmarkt omdat de garantie vervalt bij nieuwe auto's als deze worden omgebouwd. Dit zou opgevangen kunnen worden door afspraken te maken met verzekeraars. Voor E85 moet er wel een extra pomp bijkomen op tankstations evenals een bevoorradingsketen, wat om investeringen vraagt (A1 & C1).
* Het is bij biobrandstoffen een grote uitdaging om de eindgebruiker te overtuigen om over te stappen. Hiervoor is eerst een bewustwordingscampagne nodig die de optie biobrandstoffen onder de aandacht brengt (D1).
- Algemeen is het belangrijk dat de overheid steun geeft bij het gehele innovatieproces tot en met de operationele fase. Hierbij zijn investeringssubsidies niet passend, maar wel bijv. subsidies die zorgen dat biobrandstoffen op een gelijk prijsniveau komen als andere brandstoffen (A2).

Interview Anouk van Grinsven

Biobrandstoffen - 7-3-2018 – Delft
Beleidsonderzoeker bij CE Delft op het onderwerp hernieuwbare energie in transport. Europese richtlijnen RED en FQD, ILUC-richtlijn (duurzaamheid biobrandstoffen).

Factor	Score	Importance
A.1 Investment cost required	Low	8
De investeringskosten zijn laag bij biobrandstoffen, maar de operationele kosten zijn hoger. Als je al een CNG-auto hebt hoeft deze voor GroenGas niet te worden aangepast. Voor een benzineauto E85		

moet de motor worden omgebouwd, deze kosten zijn beperkt. Bij biodiesel (HVO) hoeft niets te worden aangepast aan de auto.		
A.2 Expected pay-back time at 0 euro/ton	Low	8
Er wordt bij biobrandstoffen en andere alternatieve brandstoffen naar TCO (total cost of ownership) gekeken in plaats van de terugverdientijd van een investering. De kostenstructuur van rijden op biobrandstoffen is namelijk lage investeringskosten maar structureel hogere brandstofkosten. Bij het berekenen van de TCO van een bepaald type auto wordt gekeken naar investering, operationele kosten (brandstofkosten) en hoeveel ermee gereden wordt (aantal km aanname).		
A.3 Difficulty in financing investment	Low	8
De kosten om een motor aan te passen (E85) zijn niet erg hoog waardoor financiering niet moeilijk is (vandaar score low). Door producenten moet er wel veel geïnvesteerd worden in biobrandstoffabrieken. Het vertrouwen vanuit de bank over deze investeringen is niet zo hoog omdat er op het gebied van biobrandstoffen geregeld iets verandert aan het beleid (bijv. het huidige ontmoedigende beleid voor het gebruik van palmolie als grondstof, terwijl in specifieke fabrieken voor deze grondstof is geïnvesteerd in 2009).		
B.1. Dependence on other actors	Medium	2
Om biobrandstoffen beschikbaar te hebben moet er logischerwijs een productieketen voor biobrandstoffen zijn met voldoende omvang. Grondstofproducenten (bosbouw, landbouw, 'producenten' van afvalstromen) opgevolgd door daarop aansluitende productiefaciliteiten. GroenGas kan administratief geregeld worden door een systeem van Garantie van Oorsprong certificaten welke toegeschreven worden aan transport. Het GroenGas wordt dan ingevoed op het aardgasnetwerk. Biodiesel kan op grote schaal gemaakt worden en ter vervanging van diesel worden aangeboden. Voor E85 moeten auto's worden omgebouwd en moeten tankstations worden aangepast.		
B.2 Number of actors	Medium	2
Bio-CNG kan administratief worden geregeld en HVO-diesel is niet anders dan normale diesel. Alleen voor het gebruik van E85 moeten huishoudens hun motor laten ombouwen. In Frankrijk en Duitsland ontstond er ophef bij de invoering van E10 brandstof. Over de aanpak van de invoering en de plek in de keten waarin wordt ingegrepen (brandstofproducent, tankstation, consument) moet dus goed worden nagedacht.		
B.3 Types of actors involved	High	2
Biobrandstofproducenten hebben een financieel belang. Autobezitters willen niet meer betalen voor hun brandstof. De discussie over duurzaam geproduceerde grondstoffen voor brandstoffen is behoorlijk moeilijk in Europa, omdat er veel landen zijn met een sterke landbouw die de productie van grondgebonden biobrandstoffen in stand willen houden.		
B.4 Responsibility unclear	Medium	2
Huishoudens voelen zich denk ik niet verantwoordelijk voor het terugdringen van hun uitstoot door transport. Het is voor hen financieel niet interessant omdat er geen terugverdientijd is bij biobrandstoffen. Huishoudens zullen vanwege de meerkosten alleen op biobrandstoffen overgaan als dit vanuit de overheid verplicht wordt. In veel landen wordt de verantwoordelijkheid voor de verduurzaming van brandstoffen bij de brandstofleveranciers neergelegd door middel van verplichtingen.		
C.1 Physical embeddedness	Medium	4
Biodiesel (type HVO) kan op grote schaal geproduceerd worden en heeft chemisch dezelfde eigenschappen als normale diesel, dit kan dus direct vervangen worden. De beschikbaarheid van grote hoeveelheden gebruikt frituurvet/ UCO (used cooking oil) is wel een probleem. Voor de verkoop van E85 moet een tankstation evt. een nieuwe pomp plus opslagtank aanleggen.		
C.2 Disturbs regular operation	Low	4
Motorombouw nodig bij E85 auto's, wat een beperkte ingreep is.		
C.3 Technology uncertainty	Low	4
Er zijn nu biobrandstoffen op de markt dus de technologische onzekerheid laag. Er is wel nog een discussie over hoeveel CO_2 er met deze brandstoffen wordt gereduceerd qua uitstoot. Dit is afhankelijk		

van de grondstof voor de brandstof. Er is hierover geen wetenschappelijke consensus, dus is nu gekozen om brandstoffen in te delen in wel en niet land gebonden brandstoffen, waarbij gefocust wordt op het stimuleren van niet land gebonden grondstoffen. Autobezitters vinden het ook belangrijk dat de biobrandstof dezelfde performance levert als fossiele brandstoffen. Dit is bij biodiesel (HVO) wel het geval. Bij FAME (ander type biodiesel) kunnen er wel problemen optreden bij hogere blends (bijmenging bij fossiele diesel).		
D.1 Outside of thinking scope of actor	High	6
De meeste huishoudens zijn niet bezig met de duurzaamheid van hun brandstoffen. Ze kijken voor groener transport naar elektrische auto's. Velen weten ook niet dat er nu biobrandstoffen worden bijgemengd in benzine.		
D.2 Frequency of opportunity	Low	8
Er kan iedere keer gekozen worden bij de pomp bij bijv. diesel of men biodiesel of gewone diesel wil tanken. Dit geldt ook voor de keuze tussen GroenGas en CNG. Bij E85 moet na ombouw wel telkens deze brandstof getankt worden. Het hoge rapportcijfer is gekozen omdat je gemakkelijk voor een andere optie kunt kiezen (bijv. vanwege de hogere kosten), de autobezitter moet telkens de 'andere' keuze maken.		
D.3 Requires change in behaviour	High	6
Men moet nog steeds naar het tankstation, maar wel telkens de andere tank kiezen.		

Aanvulling tabel
- De scores in de tabel zijn ingevuld vanuit het perspectief van barrières voor huishoudens. Soms is ook nagedacht over wat barrières kunnen zijn verder in de keten, deze zijn in de tekst weergegeven. De schaalniveaus bij biobrandstoffen maken het lastig om de tabel eenduidig in te vullen, biobrandstofproducenten kennen andere barrières dan huishoudens.
- Er was een interessante discussie over D2 en D3. De autobezitter kan bij iedere tankbeurt overstappen op een andere brandstof, dit geeft veel momenten om op biobrandstof te gaan rijden, maar ook veel mogelijkheden om voor de goedkopere fossiele brandstof te kiezen. De vraag is dus of dit een lage barrière is in dit geval. Bij bijv. plug-in hybrid auto's zie je ook dat mensen vaker dan verwacht kiezen om op diesel te rijden. Je moet het blijven vertonen van goed gedrag stimuleren.
- Categorie A is moeilijk toe te passen op biobrandstofauto's. Als verschillende type auto's vergeleken worden, bijv. EV, waterstofauto's en rijden op biobrandstof, wordt gekeken naar de total cost of ownership. Hierin worden de investeringskosten, operationele kosten (brandstofkosten) en het verwacht aantal km per jaar bekeken.
- Biomassabeschikbaarheid kan een probleem zijn voor biobrandstoffen. Wat is voor de biomassa de meest hoogwaardige toepassing?
- De vraag bij biobrandstoffen voor personenvervoer is of je hierop wil inzetten. Elektrisch vervoer is nu veelbelovend voor particulieren. Er wordt bij biobrandstoffen ook veel gekeken naar toepassingen in de binnenvaart, scheepsvaart, zwaar wegtransport en luchtvaart. Het aantal actoren dat hiervoor overtuigd moet worden is kleiner. Ook maakt dit type actoren ander soort investeringsbeslissingen dan huishoudens.

Missende factoren
De publieke perceptie van biobrandstoffen is een belangrijke barrière. De huidige perceptie is dat biobrandstoffen slecht zijn. Dit beeld van jaren geleden, toen nog minder bekend was over de eisen waaraan biobrandstoffen moeten voldoen om deze duurzaam te maken is bij het publiek blijven hangen (zoals het uitfaseren van palmolie en eisen rond indirect land use change (ILUC)). Deze barrière is qua belangrijkheid gescoord op een 8.

Verbanden
- De hogere brandstofkosten zijn een barrière voor autobezitters om telkens te blijven kiezen voor de biobrandstof (A en D2, D3).

Veranderingen ten opzichte van tien jaar geleden
De productieketen van biobrandstoffen is in de afgelopen tien à vijftien jaar opgezet. Ook is er meer duidelijkheid over de eisen die nodig zijn voor de productie van duurzame briobrandstoffen. De hogere brandstofkosten zijn hetzelfde gebleven. Er zal een omslag komen van FAME-diesel naar HVO-diesel.

HVO heeft chemisch vrijwel dezelfde eigenschappen als normale diesel. FAME kan maar beperkt worden bijgemengd bij diesel zonder dat dit problemen voor de auto oplevert.

Maatregelen

- Sterk overheidsbeleid op de lange termijn is nodig om partijen voldoende te laten investeren in de productie van biobrandstoffen. Zekerheid kan gegeven worden door het instellen van een verplichting (A3).
- De prijs van biobrandstoffen kan aantrekkelijker gemaakt worden door fossiele brandstoffen extra te belasten (A). Dit kan door beleid in te voeren dat recht doet aan de CO_2-reductie die gerealiseerd wordt door het gebruik van biobrandstoffen.
- Om autobezitters te overtuigen van het gebruik van biobrandstoffen zijn campagnes nodig gefocust op gedragsverandering. Deze moeten zorgvuldig worden opgezet, anders kan een campagne een averechts effect hebben. Dit onderwerp is lastig te communiceren omdat er veel verschillende opties zijn. De overheid moet dan kiezen op welke groep actoren deze zich zou willen focussen (D).

B.4 Geothermal Energy

Interview Martin Hogeboom

Geothermie - 20-2-2018 – Naaldwijk
Omgevingsmanager Trias Westland – project Ultradiepe Geothermie

Factor	Score	Importance
A.1 Investment cost required	High	6
Flinke investering. Veel projecten zijn het initiatief van (een paar) individuele tuinders die voor henzelf met hun buren een geothermieput willen slaan. Zij investeren zo kosten efficiënt mogelijk, waardoor er bespaard wordt op bijv. de duurzaamheid van het materiaal zoals de dikte van de verbuizing. Hierdoor ontstaan (onbedoeld) aanzienlijke risico's, zoals gaten in de buizen door corrosie, waardoor een put uiteindelijk niet goed werkt. Dan moet er opnieuw worden geïnvesteerd (vervanging buizen of nieuw boorgat maken). De benodigde financiële ruimte is er dan vaak niet meer.		
A.2 Expected pay-back time at 0 euro/ton	High	6
Putten worden idealiter voor 30 jaar in gebruik genomen. De terugverdientijd hangt ook af van de prijs van andere energiebronnen en de CO_2-prijs. Op dit moment geldt dat er zonder subsidie geen rendabele business-case is.		
A.3 Difficulty in financing investment	High	6
Het is best lastig om de financiering rond te krijgen omdat er veel partijen in het spel zijn. De SDE+-regeling en garantieregeling zijn de beschikbare subsidies. Bij het Trias project heeft de gemeente ook een garantstelling gedaan. Er zijn meerdere banken en verzekeraars met hun juridische en technische specialisten. Doordat NL van het gas af moet is op landelijk niveau een zeer groot draagvlak om op geothermie in te zetten. Het valt daarom te verwachten dat subsidieregelingen nog wel even blijven bestaan hetgeen de partijen zekerheid geeft.		
B.1. Dependence on other actors	High	7
Er zijn een aantal vergunningen nodig voor een proefboring: Omgevingsvergunning (niet moeilijk), opsporingsvergunning (technisch onderzoek nodig door adviesbureaus en goedkeuring door SodM). Andere betrokken partijen zijn: tuinders (49) als toekomstige afnemers van warmte, de aandeelhouders HVC, Capturam en Royal Flora Hollend, de banken, EZ, gemeente en andere partijen die subsidies en garanties verstrekken en de omwonenden van de boorput. Deze tuinders hebben contracten getekend waarin zich hebben gecommitteerd om voor een lange periode warmte af te nemen. Geothermieprojecten zijn wat betreft het aantal stakeholders en diversiteit tussen stakeholders een stuk beperkter dan bij grote projecten als wegverbredingen of Maasvlakte 2. Voor het Trias project bestaat een groot maatschappelijk en bestuurlijk draagvlak, dit kan bij projecten in gemeentes met een meer instabiele ondergrond anders zijn (angst voor seismiciteit en kans op schade aan woningen). De afhankelijkheid van SodM voor de goedkeuring van de opsporingsvergunning en het toezicht tijdens het boren zijn best een lastige opgaven Op technisch gebied zijn de eisen vanuit SodM niet altijd eenduidig. Bijv. is het plaatsen van geofoons (apparaten die trillingen vaststellen) wel of niet verplicht gedurende de boorfase? Dit kan een remmend effect hebben op het ontstaan van projecten, omdat dit een onzekere factor is voor financiers.		
B.2 Number of actors	Low/medium	4
Een aantal, beperkte kring van stakeholders. In verstedelijkt gebied kan het aantal hoger zijn en meer complex. Hoeft geen remmende factor te zijn.		
B.3 Types of actors involved	High	3
Actoren bij het Trias project hebben veelal dezelfde belangen: zekerheid over warmtelevering tegen vaste kostprijs, afname fossiele brandstoffen (CO_2), versterking Greenport. De afstemming tussen initiatiefnemers, adviesbureaus, operators en bevoegde instanties (Min EZ, SodN en gemeenten en provincies) zijn meest complexe relaties, ook omdat er in NL maar beperkte ervaring is opgedaan met geothermie, terwijl de druk op de realisatie van meer projecten snel toeneemt. De diversiteit in belangen kan in een meer verstedelijkte omgeving problematischer zijn (belangrijkheid = 7 bij gemeentes).		
B.4 Responsibility unclear	High	4

De relatie tussen de initiatiefnemer en SodM is nog niet helemaal helder. SodM heeft toezichthoudende rol, maar is in kleinere projecten onbedoeld verworden tot adviseur. In het Trias project is dit niet zo'n grote barrière omdat er aan de kant van de opdrachtgever veel expertise is. Bij kleinere projecten bleek dit problematisch omdat zij vaak maar beperkte kennis hebben en hierdoor minder in staat zijn het gesprek met SodM te voeren(belangrijkheid is 6). SodM heeft dit probleem in een ongevraagd advies bij de Minister van EZ in zomer van 2017 aangekaart (bron: Staat van de sector etc)		
C.1 Physical embeddedness	Low/medium	2
Na de booractiviteiten zie je enkel wat buizen uit de grond steken. Doordat dit vrijwel niet zichtbaar is ervaren mensen geen verandering in de omgeving. Een warmtewisselaar wordt meestal in een klein huisje gezet, wat niet opvalt in een omgeving voor kassen en ketelhuizen.		
C.2 Disturbs regular operation	Low	2
200 boren dagen vs 30 jaar gebruik maken van de put. Als de put werkt kan deze warmtevoorziening ingeregeld worden. Dit is een overgang voor de tuinder, maar warmte blijft warmte.		
C.3 Technology uncertainty	Medium/High	4
In Nederland zijn nog maar vijftien projecten gedaan dus er is nog niet veel ervaring voor gas en oliebedrijven met specifiek geothermie. De ondergrond blijft een onvoorspelbare factor omdat daar nog niet zoveel kennis over is. Reguliere projecten vinden plaats in de Onderkrijt-laag welke iets beter voorspelbaar is dan de Trias-laag (ultradiepe geothermie). Bij dit project moest bijv. een boorkop vervangen worden en een andere 'afslag' in de ondergrond genomen worden.		
D.1 Outside of thinking scope of actor	Low	1
Tuinders zijn goed bekend met geothermie als warmtebron.		
D.2 Frequency of opportunity	Medium	9
De locaties waar geothermie mogelijk is in Nederland zijn beperkt (slechts een aantal provincies). De locatiegebondenheid is de beperkende factor voor de mogelijke projecten.		
D.3 Requires change in behaviour	Low	2
Voor de tuinder zorgt een andere warmtebron niet voor andere dagelijkse bezigheden.		
E.1 Missende factoren: Public acceptance	Medium	4
Maatschappelijke acceptatie is een noodzakelijke voorwaarde van de totstandkoming van een project. Hierbij hoort ook de vraag: kan een lokaal geothermisch project inzet worden van een landelijk debat (nut-en noodzaakdiscussie) of kan een project slechts op lokale/regionale belangstelling rekenen? Op landelijk niveau is er een breed draagvlak om in het kader van de energietransitie in te zetten op geothermie (gezien de evidente voordelen). Er is draagvlak bij bewindslieden en politieke partijen in het algemeen. Ook natuur- en milieuorganisaties steunen deze energiebron. Er is wel kritiek indien er geopereerd wordt in gebieden met seismiciteit (zie discussie over Warmtestad Groningen). Relevante partijen voor dit onderwerp zijn: natuur en milieuorganisaties, lokale groepen, omwonenden, wetenschappers, opiniemakers. In het Westland is geothermie breed geaccepteerd, in stedelijke gebieden kan dit anders liggen (belangrijkheid is 6). Het kan dat inwoners onterechte associaties maken tussen geothermie en het aardgasdossier in Groningen(wat in een slecht daglicht staat).		

Aanvulling tabel

Ieder geothermieproject start met een opsporingsvergunning < Op dit moment zijn er door het ministerie nog geen winningsvergunningen verleend voor project die al operationeel zijn. Winning gebeurt bij geothermie echter al direct na een proefboring (anders loopt de circulatie in de put gevaar; kans op verstoppingen). Het wettelijk instrumentarium schiet dus specifiek voor geothermische projecten te kort. . Dit geeft onzekerheid voor de initiatiefnemers en financiers en heeft een remmende werking op het van de grond komen van projecten. De locatiegebondenheid van geothermie is ook een belangrijke factor. Dit aspect is nu geplaatst onder D2, frequency of opportunity.

Tijdens het interview werd gezegd over de factoren 'ze zijn nogal abstract' en 'we waren al weer heel erg aan het wapperen' (er werd steeds tussen de factoren geschakeld). C2 was ook een moeilijk te beoordelen factor.

Verbanden tussen barrières
De ondergrond en diepte van de aardlaag waarin geboord wordt (D2) is bepalend voor het putontwerp wat de business case voor een project bepaalt (A1 & A2). De onzekerheid over of er een bron gevonden wordt bij een proefboring in combinatie met de nog niet geheel duidelijke (technische) eisen van SodM zorgen voor onzekerheid voor financiers (D2, A3, B1). Indien extra onderzoek of uitvoeringsmaatregelen nodig zijn, willen de financiers hier dan voor betalen? Het politiek en maatschappelijk draagvlak is bij het Trias project geen barrière, maar kan in andere projecten wel een obstakel zijn . Daarnaast is de ontwikkeling van de energieprijs een onzekere factor voor de terugverdientijd van projecten.

Veranderingen ten opzichte van tien jaar geleden
Het politiek draagvlak voor geothermie is in de laatste tien jaar gegroeid, omdat Nederland versneld haar afhankelijkheid van gas moet verlagen door de aardbevingen in Groningen. Ook zijn er klimaatafspraken gemaakt in 2015 in Parijs die voor urgentie zorgen. Er heeft in kleine mate technologische ontwikkeling plaatsgevonden, in Nederland zijn nu vijftien geothermieprojecten.

Maatregelen om barrières te verlagen
- Door onderzoek en projecten de professionaliteit van partijen die betrokken zijn bij geothermieprojecten verhogen (B1, B3, B4)
- Informatiebijeenkomsten voor bewoners en belangstellenden, nieuwsbrieven, persberichten, 24/7 bereikbaar voor vragen (hiervoor heeft Trias een professionele organisatie ingehuurd), website met uitgebreide uitleg over geothermie (B1 & B3)
- Succesverhalen creëren, deze zijn nodig om mensen te overtuigen (B1 & publieke acceptatie)
- Tegenslagen overwinnen in projecten (zie je wel, het kan wel) (B1 & publieke acceptatie)
- Kleinere demonstratieprojecten uitvoeren in niet-stedelijk gebied om kans op publieke weerstand te voorkomen en ervaring op te doen (B1 & C3)
- Container plaatsen om geluid tegen te houden (C2)
- In stedelijk gebied extra budget nodig voor voorlichting, extra onderzoeken ter geruststelling van bewoners, bijv. geofoons installeren voor de beeldvorming al is de kans op trillingen minimaal, bouwkundige (opnamen van gebouwen voor en na project (B1 & publieke acceptatie).

Interview Frank Schoof
Geothermie - 27-2-2018 – Delft
Voorzitter Platform Geothermie. Het platform heeft deelnemers in de gehele keten: provincies, gemeentes, kennisinstellingen, adviesbureaus, onderzoeksbureaus, toeleveranciers en operators.

Factor	Score	Importance
A.1 Investment cost required	High	8
Bij projecten in de glastuinbouw zitten de kosten vooral in het boren van de put (verticale buizen). Als er ook een distributienet nodig is (aantal tuinders of warmtenetwerk in de gebouwde omgeving) zorgt dit voor een substantiële extra investering (het distributienetwerk kan wel twee keer zo duur zijn als de put).		
A.2 Expected pay-back time at 0 euro/ton	High	8
Door de beperkte ervaring zijn de capex (aanleg put) en de opex (operating kosten) nu nog hoger dan zij naar inschatting in de toekomst zullen zijn.		
A.3 Difficulty in financing investment	High	8
Subsidie is nodig om projecten van de grond te laten komen. Mét subsidie is de terugverdientijd rond de 15 jaar. Ook is in veel gevallen de bank nodig voor een lening. Deze kijkt naar de risico's en rekent daar een premie voor in, hoe meer partijen deelnemen hoe groter het risico en dus de premie. Ook het geologisch risico speelt een belangrijke rol bij de financiering.		
B.1. Dependence on other actors	Medium	6
Projectniveau: projectontwikkelaars, onderleveranciers, warmtebedrijf (beheerder netwerk evt verticaal en horizontaal netwerk gescheiden), klanten, vergunningsverleners en omwonenden. De wetgeving (voor het verkrijgen van de benodigde vergunningen) wordt waarschijnlijk binnenkort aangepast,		

waardoor de afhankelijkheid van de vergunningsverleners kleiner wordt. In de gebouwde omgeving heb je afnemers nodig voor de warmte: een warmtebedrijf dat de warmte via een warmtenetwerk verspreidt en 'daarachter' de afnemers van deze warmte (huishoudens). Zonder deze afnamezekerheid (dus vraag) komt er geen geothermieproject.		
B.2 Number of actors	Medium	8
Het aantal actoren bij een doublet in de tuinbouw is beperkt. In de gebouwde omgeving is dit aantal al groter, omdat huishoudens die worden aangesloten op een warmtenet het aantal actoren vergroten.		
B.3 Types of actors involved	Medium	3
Omwonenden hebben potentieel tegengestelde belangen ten opzichte van de uitvoerende partijen van een project. Omwonenden hebben potentieel tegengestelde belangen ten opzichte van de uitvoerende partijen van een project. In de gebouwde omgeving is een meer diverse groep te verwachten, omdat huishoudens in een wijk waarschijnlijk verschillende meningen hebben over de overgang van gasverwarming naar een warmtenetwerk.		
B.4 Responsibility unclear	Medium	6
De verantwoordelijkheden binnen een project zijn helder. Op een hoger schaalniveau is dit nog niet duidelijk: Wie is verantwoordelijk voor de opschaling van geothermie in Nederland (in 2030 50 PJ)? Wie gaat dit organiseren en bijv. klanten voorlichten over warmtenetwerken? Uit de recent verschenen beleidsbrief Geothermie blijkt dat de overheid dit deels naar zich toetrekt. Zij heeft o.a. taken gegeven aan EBN: Verbetering kennisuitwisseling en het in kaart brengen van de ondergrond.		
C.1 Physical embeddedness	Medium	3
Bij projecten bij tuinders is het doublet vrijwel niet te zien. In de gebouwde omgeving is een warmtenetwerk nodig wat onder de grond zit. Wel is vaak een gasscheider nodig en een hulpketel. Dit betekent toch dat er een zeker ruimtebeslag (bovengronds) is.		
C.2 Disturbs regular operation	High (gebouwde omgeving), low/medium (tuinders)	3
Voor een project in de gebouwde omgeving moet een warmtenet worden aangelegd, wat een behoorlijke impact heeft, omdat de straten tijdelijk openliggen. Bij projecten in de glastuinbouw is de overlast van werkzaamheden beperkter.		
C.3 Technology uncertainty	High	10
Geologische onzekerheid is het grootste risico bij geothermie: Je weet nooit precies wat er in de ondergrond zit. Op andere gebieden zoals boortechnieken of de aanleg van warmtenetwerken is weinig onzekerheid.		
D.1 Outside of thinking scope of actor	Medium	6
Geothermieprojecten worden alleen gestart vanuit een wens voor een duurzame warmtebron. Een aantal gemeentes zijn bekend met geothermie, aan hen wordt dan gevraagd of zij ook al bezig zijn met een warmtenetwerk, aangezien dit essentieel is voor de distributie van warmte. Voor de industrie is diepere geothermie (>5 km) vaak vereist in verband met temperatuur. Hier loopt onderzoek naar. Een derde mogelijkheid is ondiepere geothermie (< 1000 meter) waar een warmtepomp vereist is. Hier is de investering lager, maar zijn de operationele kosten (relatief) hoger.		
D.2 Frequency of opportunity	High	8
De timing moet goed zijn, als mensen net een nieuwe warmte-installatie hebben aangeschaft (cv-ketel of andere warmtebron bij tuinder), willen zij waarschijnlijk pas overstappen op een warmtenet/ geothermische bron als de eerdere investering is afgeschreven.		
D.3 Requires change in behaviour	Medium	8
Voor een afnemer in de tuinbouw verandert er weinig, er is enkel een andere warmtebron. Voor een huishouden verandert er meer, deze gaat bijvoorbeeld elektrisch koken in plaats van op gas.		

Aanvulling tabel

- De factoren zijn duidelijk. De score die je moet geven is voor mij wel afhankelijk van vergelijking met andere abatement measures. CO_2 reduceren binnen de warmtevoorziening is anders dan CO_2 reduceren binnen de elektriciteitsopwekking. Dit maakt het invullen van low, medium en high best moeilijk.
- Er zijn grote verschillen tussen geothermieprojecten in de gebouwde omgeving (veel afnemers en warmtenetwerk nodig) en projecten in de glastuinbouw en industrie (een of enkele afnemers, evt. beperkt

distributienet nodig). Deze verschillen zijn in de tabel aangegeven. De cijfers in de rechterkolom van de tabel zijn gegeven voor projecten in de glastuinbouw.

Verbanden tussen factoren
- Bij een project in de gebouwde omgeving moeten huishoudens anders gaan koken als zij in plaats van op gas, elektrisch gaan koken (C1, D3).
- Geologische onzekerheid zorgt voor risico, het dekken van risico zorgt voor hogere investeringskosten en maakt het aantrekken van financiering moeilijker (C3, A).
- De lange terugverdientijd van geothermische projecten maakt het moeilijker om financiers aan te trekken, omdat dit een hoger risico met zich meebrengt (A2, A3).
- Het financieren van een warmtenetwerk is lastig, omdat er een onzekerheid is of huishoudens ook warmte willen afnemen van dit warmtenetwerk (B1, A).

Veranderingen ten opzichte van tien jaar geleden
De meeste barrières zijn ongeveer gelijk gebleven. De technologische onzekerheid (C3) is iets gedaald omdat er in de afgelopen jaren meer ervaring is opgedaan in geothermieprojecten: 'van super high naar high'. De recente beleidsbrief Geothermie moet nog zijn effect hebben in de verduidelijking van de regelgeving en de verdeling van de verantwoordelijkheden (mbt onderzoek naar de ondergrond en verbetering van de kennisdeling). Er zijn op dit moment nog steeds geen geothermieprojecten in de gebouwde omgeving. Binnenkort start er één in Den Haag, maar hiermee is geothermie (of warmtenetwerken) in de gebouwde omgeving nog geen 'standard practice'. Doordat er nu iets meer geothermieprojecten in Nederland zijn uitgevoerd (in de glastuinbouw) is er iets meer kennis op dit gebied. Er zijn nog maar enkele partijen die meerdere geothermieprojecten uitvoeren, geen enkele partij heeft langjarige ervaring.

Maatregelen
- Het aanpassen van de regels voor vergunningsverlening vergemakkelijkt de vergunningsprocedure en verkleint de afhankelijkheid van vergunningverlenende partijen (B1).
- Kennisuitwisseling tussen projecten/ operators is nodig om de projectkosten te verlagen en de veiligheid van projecten te verhogen. Zo kan innovatie plaatsvinden wat de kosten verlaagt en de betrouwbaarheid van projecten verhoogt. Een hogere betrouwbaarheid zorgt voor een lager risico, wat de financiering vergemakkelijkt (A).
- Om innovatie mogelijk te maken, moet er meer vraag komen naar warmte, en dan (dus) naar geothermieprojecten, zodat innovaties getest kunnen worden. Als een bedrijf maar eens in de twee jaar een geothermieproject onderneemt, zal deze ook niet investeren in innovatie en duurt de innovatiecyclus te lang. Hierbij is vooral het zicht op de afzet van de warmte belangrijk. Warmtebedrijven moeten de wil hebben om een warmtenetwerk op te zetten. Hierbij is een hoge mate van zekerheid nodig dat de burger hiervan daadwerkelijk warmte wil afnemen.

Interview Mike Woning
Geothermal Energy - 7-3-2018 – Delft
Voorzitter Delft Aardwarmte Project (DAP) stimuleert onderzoek, onderwijs en ontwikkeling (3O) naar geothermie op de TU Delft. DAP was tevens initiator om een geothermiebron te realiseren op de campus van de TU Delft voor onderzoek en warmtelevering. . Mike Woning was betrokken bij het projectmanagement van de eerste geothermiedoublet vanuit Visser & Smit Hanab. Hij is nu werkzaam bij Deltares.

Factor	Score	Importance
A.1 Investment cost required	High	9
Flinke bedragen die tuinders niet direct op de bankrekening hebben staan, 8 á 10 miljoen euro.		
A.2 Expected pay-back time at 0 euro/ton	Medium	9
Dit is een zeer belangrijke barrière. Er zijn verschillende verhalen over de terugverdientijd, maar tussen 5 en 12 jaar (is o.a. afhankelijk van welke subsidie kan worden meegenomen).		
A.3 Difficulty in financing investment	Medium/High	7

Om een project van de grond te krijgen zijn subsidie en een banklening nodig. De bank vraagt hierbij om een bepaalde zekerheid over de terugverdientijd. Deze is afhankelijk van de verwachte hoeveelheid warmte die een operator naar boven kan halen (op deze duurzaam geproduceerde warmte wordt SDE+-subsidie gegeven). Dit wordt uitgedrukt met de P50 en P90 (het vermogen dat de put met een kans van 50/90% tenminste kan leveren). De hoeveelheid warmte die een put kan leveren is afhankelijk van factoren als doorlatendheid, temperatuur en connectiviteit in de put en dit zijn vaak onzekere factoren. Door wat langere ervaring op het gebied van geothermie hebben banken gezien hoe de voorspellingen over output vooraf (desk studies) zicht verhouden tot de realiteit.		
B.1. Dependence on other actors	Medium	6
Een aantal betrokken actoren: Bank, subsidieverlener, overheid/gemeente als vergunningsverlener, omwonenden, uitvoerder, buren als die ook vergunningen hebben (interferentie kan opbrengst van de put beïnvloeden), evt. back-up nodig contract met gasleverancier voor koude wintermaanden. Specifiek in het project met geothermie op de campus zijn er aan de kant van de afnemer van de warmte de volgende partijen betrokken: TU Delft (als warmteafnemer en onderzoeksinstituut) en de woningcoöperatie. Voor de TU Delft is het lastig aan te geven hoeveel warmte zij zullen afnemen, omdat dit afhankelijk is van de benodigde renovatie van gebouwen.		
B.2 Number of actors	Low	3
Het aantal partijen om een project te realiseren is beperkt.		
B.3 Types of actors involved	Low	4
Omwonenden hebben evt. tegengestelde belangen aan die van de tuinder die voornemens is een geothermieput aan te leggen. Een naburige tuinder met een put is evt. tegen als de nieuwe put het rendement van zijn put negatief beïnvloedt. De voormalige energieleverancier zal niet blij zijn met het afzeggen van het contract, al blijft de WKK en gasleiding meestal bestaan. Specifiek in het Delft Aardwarmte Project zijn er tegengestelde belangen binnen de TU Delft: FMVG (vastgoed) wil zekerheid van levering en een lage prijs van de warmte, terwijl de onderzoekers van de TU Delft graag experimenten willen uitvoeren en veel monitoringsapparatuur willen plaatsen. Ook is hierbij nog een woningcoöperatie betrokken met vergelijkbare belangen als FMVG.		
B.4 Responsibility unclear	Low	2
Duidelijk binnen een project, de drive voor tuinder om een project aan te leggen is economisch.		
C.1 Physical embeddedness	Low	3
Voor een geothermieput moeten twee boringen gemaakt worden, daar zie je aan het oppervlak weinig van. Daarnaast is een warmtewisselaar nodig in plaats van een WKK. De kas moet evt. worden aangepast omdat het temperatuurregime van een geothermische put anders is dan dat van een WKK.		
C.2 Disturbs regular operation	Medium	2
Tijdens de aanleg van het project moet de boortoren op het terrein komen te staan. Dit kan eventueel voor wat moeilijkheden in de logistiek zorgen op het terrein (en geluidsoverlast voor omwonenden).		
C.3 Technology uncertainty	Medium	7
In theorie is veel bekend over geothermie en hoeveel warmte dit kan opleveren. In de praktijk pakt dit soms anders uit. In Nederland is de sector niet heel volwassen (15 projecten op dit moment). Dit zijn vooral tuinders, wat kleine bedrijven zijn. Deze kiezen sneller voor een goedkope oplossing in de aanlegfase, wat soms zorgt voor problemen in de operationele fase.		
D.1 Outside of thinking scope of actor	Low	2
Tuinders zijn zich ervan bewust dat de optie geothermie voor warmtevoorziening bestaat.		
D.2 Frequency of opportunity	Low/Medium	1 of 10*
Een tuinder kan ieder moment beginnen met onderzoeken of geothermie een optie is. Soms kan het aflopen van een langjarig gascontract hiervoor een aanleiding zijn. Of geothermie mogelijk is, is locatie-afhankelijk. Dit kan in vrij veel delen in Nederland.		
D.3 Requires change in behaviour	Low/Medium	3
Een aantal relatief kleine aanpassingen aan de dagelijkse werkzaamheden zoals het monitoren van de opbrengsten van de put en het verschonen van filters.		

Aanvulling tabel
- Extra uitleg was nodig bij D1 en D2. *Vooral D2 was lastig in te vullen voor geothermie, omdat dit zeer locatieafhankelijk is.
- Tijdens het interview kwam een aantal keer terug dat er een verschil is tussen de theorie en praktijk qua risico bij geothermieprojecten in Nederland. Dit komt door kostenbesparingen op de aanleg van putten welke zich vertalen in hogere operationele kosten.

Verbanden
- Er is een verband tussen financiering en de investeringskosten, omdat het afhankelijk is van de hoeveelheid welke de bank wil financieren of de investering haalbaar is voor de tuinder (A1, A3).
- De tuinder is afhankelijk voor financiering van de bank en subsidieverlener (beïnvloedt terugverdientijd) (A2, A3, B1).
- Bij tegengesteld belangen wordt de afhankelijkheid gecompliceerder (bijv. van toestemming naburige tuinder om een put aan te leggen, al komt niet vaak voor) (B1, B3).
- Het geologisch risico geeft onzekerheid voor de bank. Daarnaast geeft besparing op de investeringskosten grotere risico's voor het goed functioneren van de put tijdens de operationele fase (A3, C3).

Veranderingen ten opzichte van tien jaar geleden
- Er is nu een helderder subsidieprogramma, waarmee het risico van de eerste boring deels wordt afgedekt door de overheid (A1)
- De SDE+ regeling was minder of niet aanwezig tien jaar geleden. Deze geeft een subsidie op de hoeveelheid duurzaam geproduceerde energie (A2).
- Banken kennen tegenwoordig het klappen van de zweep beter dan tien jaar geleden. Zij overzien de risico's van geothermie bezig en zijn bekend met de techniek (A3, B1). Dit kan een positief of negatief effect hebben.
- Qua uitvoeringstechniek is er niet veel veranderd ten opzichte van tien jaar geleden (C).
- De vergunningverlening is iets aangepast en hiermee gemakkelijker geworden (B1).

Maatregelen
- Meer kennis en kennisdeling is nodig om te zorgen dat projecten stabielere rendementen halen (C3). Kwalitatief goed uitgevoerde boorprojecten kunnen dienen als showcases om banken ook meer vertrouwen te geven. De kinderziektes zijn eruit bij geothermie als de projecten zorgvuldig worden uitgevoerd.
- De SDE+ regeling en subsidies geven financiële ondersteuning aan tuinders (A1, A2).

Interview Mara van Eck – van der Sluijs

Geothermal energy - 9-3-2018 – Utrecht
Secretaris Communicatie bij DAGO (Dutch Association Geothermal Operators). Deze brancheverenigingbevordert de kennisdeling onder operators en stuurt aan op passende wet- en regelgeving voor de geothermiesector. Daarnaast ontwikkelt zij industriestandaarden voor haar leden.

Factor	Score	Importance
A.1 Investment cost required	High	8
Er zijn voor geothermie-operators relatief hoge investeringen nodig voor de aanleg van een geothermieput (15 à 20 miljoen euro). Een significant deel van de investering moet vooraf gedaan worden. Als vooraf niet voldoende geïnvesteerd wordt in een goede boring, blijken de operationele kosten hoger uit te vallen dan voorspeld. Er wordt nog gezocht naar wat er essentieel is om een optimaal putontwerp te maken en welke investering hierbij hoort. De investering voor een warmtenet (als deze nodig is voor warmteafzet) is ongeveer gelijk aan de kosten van een geothermieput.		
A.2 Expected pay-back time at 0 euro/ton	Medium/High	6
Dit is afhankelijk van het project. Projecten worden ontwikkeld vanaf 10 tot 15 jaar. De SDE+ subsidie wordt voor 15 jaar gegeven. Tuinders, die erover denken om geothermie-operator te worden of deze in de hand te nemen, denken op de lange termijn bij het nemen van investeringsbeslissingen, omdat de bedrijven vaak binnen de familie blijven en locatie gebonden zijn.		
A.3 Difficulty in financing investment	Medium	7

De Rabobank heeft vrijwel alle geothermieprojecten gefinancierd. Deze bank stelt nu eisen over het eigen vermogen van een tuinder/geothermie-operator (30 à 40% van de investering) voor de uitgifte van leningen. Omdat niet veel initiators voor projecten in hun eentje over dit vermogen beschikken, worden projecten tegenwoordig vaker in consortia gedaan van zes tot tien tuinders/geothermie-ontwikkelaars. Er zijn daarnaast ook bedrijven als ECW welke uit de geldstroom van draaiende geothermiedoubletten nieuwe projecten kan financieren. Dit maakt het makkelijker om andere financiering te verkrijgen.		
B.1. Dependence on other actors	High	10
Betrokken actoren zijn: gemeente (bestemmingsplan, adviseur over vergunningen), de omwonenden, financiers, ministerie van Economische Zaken en Klimaat (vergunningen), SodM (toestemming en toezicht), TNO ondersteunt EZK met advies), RVO keert subsidie uit. Zes partijen moeten akkoord geven om een project van start te laten gaan.		
B.2 Number of actors	Low	3
Bij geothermieprojecten zijn een beperkt aantal actoren betrokken.		
B.3 Types of actors involved	Medium	7
Meestal zitten de partijen op één lijn, maar er zijn ook soms tegengestelde belangen bij geothermieprojecten. Het ministerie van Economische Zaken en Klimaat vervult bijv. een dubbelrol. Zij wil zoveel mogelijk duurzame energie in Nederland realiseren, maar is aan de andere kant vergunningsverlener. In deze rol moet zij vergunningen aan de wet toetsen. SodM en TNO geven hierover advies. SodM kijkt kritisch naar de veiligheid van projecten bij het verlenen van subsidies. De bank wil projecten stimuleren, maar daarnaast ook zekerheid over het terugkrijgen van de leningen.		
B.4 Responsibility unclear	Medium	7
Theoretisch gezien zijn de verantwoordelijkheden helder. Volgens de mijnbouwwet is de operator overal voor verantwoordelijk, maar voor de arbowet liggen deze verantwoordelijkheden anders. De geothermie-operator is sterk afhankelijk voor toestemming voor een project van andere actoren (B1), voor bijv. het tijdig uitgeven van vergunningen. Het is onduidelijk bij wie de verantwoordelijkheid ligt als vergunningen te laat worden uitgegeven.		
C.1 Physical embeddedness	Medium	5
Dit valt in principe mee. Er is een boorlocatie nodig ter grootte van één à twee voetbalvelden. Na de boring is er een klein gebouwtje met een warmtewisselaar wat onopvallend is in het landschap.		
C.2 Disturbs regular operation	Medium	5
Een boring duurt één tot twee maanden, wat voor geluidsoverlast kan zorgen bij omwonenden.		
C.3 Technology uncertainty	Medium/High	8
Er zijn bij de projecten die nu gerealiseerd zijn verschillen in hoelang onderdelen meegaan (bijv. pomp 7 jaar of 3 maanden). Als er iets kapot gaat is er een backup nodig voor de warmtevoorziening. Op technisch gebied moeten er nog een aantal verbeteringen worden doorgevoerd.		
D.1 Outside of thinking scope of actor	Medium	4
Tuinders weten dat geothermie mogelijk is om warmtevoorziening te verduurzamen, maar ze weten niet of het technisch mogelijk is op hun locatie door onzekerheid van de ondergrond.		
D.2 Frequency of opportunity	High	6
De aanleg van een geothermieput is een vrij grote investering. Het komt niet vaak voor dat een tuinder/geothermie-operator zoveel eigen vermogen ter beschikking heeft om mee te investeren. Daarnaast is het vergunningsproces een vrij lang proces. Ook moet er vooraf geïnvesteerd worden in geologisch onderzoek en een putontwerp om te kijken of het technisch mogelijk is en wat de investering zou zijn.		
D.3 Requires change in behaviour	Medium/High	5
Er is nog meer verandering nodig in hun dagelijkse activiteiten dan tuinders die geothermie-operators worden in eerste instantie dachten bij de eerste installaties. Ze krijgen een nieuwe technische installatie waar ze nog geen ervaring mee hebben. Deze moet anders onderhouden worden dan ze gewend zijn. Er zijn daarom nu ook bedrijven die de ontwikkeling als businesscase hebben (HVC, ECW, Hydreco, VSH en Wayland). Voor hen oor hen is het werken met geothermische verwarming de dagdagelijkse gang van zaken.		

Aanvulling tabel
- Bij factor D1 werd ook besproken of de tuinders naast af te weten van de optie geothermie ook kennis hadden van wat er allemaal komt kijken bij het opzetten van een geothermieproject.

Missende factoren
- De risico's bij geothermie zijn heel specifiek per regio. In Noord-Limburg is het seismisch risico bijv. hoger dan in Zuid-Holland. De vragen per project zijn oa: Hoe groot is het seismisch risico, is dit te onderbouwen, kunnen de consequenties beheerst worden? Dan na deze inventarisatie is de vraag, is er politiek draagvlak om een geothermieproject te starten? Dit speelde bijv. bij Warmtestad Groningen, hier ligt geothermie politiek gezien lastiger, al is het een vervanging voor gasverwarming. Per project is maatwerk nodig (boor je bijv. door een gasveld), geothermie is daarom niet gemakkelijk toe te passen in heel Nederland.
- Politiek en/of publiek draagvlak is een belangrijke factor voor geothermie. Is er wel of geen draagvlak en in hoeverre kan dit snel omslaan? Is er weerstand tegen projecten of vindt het publiek er niets van? Dit tweede is vaak het geval bij geothermie. Dit betekent niet dat de massa vóór geothermie is, men heeft er geen mening over en is daardoor ook gemakkelijk beïnvloedbaar voor verhalen over dit thema, omdat men geen 'referentiekennis' heeft. De mening van het publiek hierover is om deze reden relatief gemakkelijk te vormen.

Verbanden
- Rabobank vindt het moeilijk om investeringsbeslissingen (A3, B4) te nemen omdat het beleid vanuit EZ en het toezicht van SodM niet zo helder en transparant is. Hierdoor weten ze niet goed waar ze aan toe zijn.
- Investeringskosten en de terugverdientijd zijn afhankelijk van de technologische onzekerheid (A1, A3, C3).
- Er is een vrij grote afhankelijkheid voor de financiering van projecten van banken (A3, B1).

Veranderingen ten opzichte van tien jaar geleden
Het eerste geothermieproject is geboord in 2007. Toen was de investering de helft van wat deze nu is (A1). Er is nu wel een SDE+-subsidie gemaakt voor geothermie. Netto is de terugverdientijd wel langer geworden (A2). De investering voor een geothermieput is hoger geworden omdat er bij de eerste projecten geboord werd alsof er naar water werd geboord. Dit paste niet bij wat men tegenkwam in de ondergrond, dus moest er zorgvuldigere worden geboord (zoals het boren van een gasput). Dit zorgde voor een stijging van de investeringen omdat de veiligheidsmaatregelen werden uitgebreid.
Tien jaar geleden had vrijwel niemand een mening over geothermie, de diversiteit van meningen van verschillende actoren is nu groter geworden (B3).
De grote onzekerheid was toen de ondergrond, is het überhaupt mogelijk om een project te realiseren? Dit is nu een aantal keer bewezen, waardoor deze technische onzekerheid is afgenomen (C3). De overlast voor de omgeving bij het boren van een geothermieput is gelijk gebleven (C2). Tien jaar geleden dacht geen enkele tuinder aan geothermie of het worden van een geothermie-operator, nu weet iedere tuinder dat dit een optie is en zijn er bedrijven opgericht die zich bezighouden met de ontwikkeling van geothermielocaties (D1). Er zijn meer aanpassingen nodig aan de dagelijkse werkzaamheden voor operators dan jaren geleden gedacht werd (D3).

Maatregelen
- SDE+ regeling en het garantiefonds zorgen voor meer zekerheid voor de investering van de geothermie-operator (A1, A2).
- Er moet meer inzicht komen in welke risico's er zijn en hoe deze beheerst kunnen worden. Ook moeten de kosten van het beheersen van risico's beter in kaart worden gebracht evenals welke voorzorgsmaatregelen genomen kunnen worden zodat de put niet stil komt te liggen (A, C3).
- Voor de opschaling van geothermie zijn warmtenetten nodig en een afzet van de warmte. Er is regie nodig van de overheid om vraag en aanbod samen te brengen. Er is nu veel weerstand tegen stadsverwarming in de gebouwde omgeving (B4).
- Het is goed om de verantwoordelijkheden van verschillende partijen te verduidelijken en daarnaast passend beleid, wetgeving en toezicht te maken voor de sector. Deze randvoorwaarden zijn nodig om vertrouwen te geven aan de markt en financiers voor de verdere uitrol van geothermie in Nederland. De minister maakt hier op dit moment werk van (B1, B4).

Appendix C: Additional analyses results and discussion

In this appendix, several analyses that support (smaller) conclusions in chapter 4 and 5 are presented.

C.1 Underpinning choice final barrier scores

The following method was applied to conclude the final barrier scores for the abatement options. If possible, the mode was chosen as the final barrier score (for the scores 'low, low, medium', low was concluded). In-between scores' (low/medium or medium/high) were rounded up or down towards the mode. If this did not lead to a clear result, the score was derived from the background stories of the interviewees by the author. This appendix shows additional explanation of the rationale that led to the choice of the final barrier. This is only explained for large uncertainties (where two interviewees deviate from the mode).

Table C.1 Underpinning choice final barrier scores with high uncertainty

Carbon Capture Storage	
B3 (Types of actors) Scores: High, Medium, High, Medium	The high score was chosen, because opposing interests exist among the different actors (e.g. the public opposed the Barendrecht project).
B4 (Responsibility unclear) Scores: High, High, Low, Medium	The high score (also the mode) was selected as some important choices on responsibility for the safety of the storage are not yet clear. These are essential for companies to take investment decisions.
D1. (Awareness of actor) Scores: Low, High, Low, Medium	The low score (also the mode) is chosen as industrial parties are aware of the existence of this abatement option. However, the knowledge level is low on how to implement this within their company.
Biofuels	
A1 Investment costs A2 Payback period Scores: Medium/High, Medium, Low & No score, Medium, Low	The diverse scores are due to the ill-fit of the cost structure of biofuels (high operational costs, low/no investment costs). One interviewee also did not score A2. Therefore, the choice is made to indicate the issues of costs which are present with these two medium scores.
B4 Responsibility unclear Scores: Low, High, Medium	Currently private car owners are not obliged to use high percentage biofuels. Only some change to this fuel, but many people do not feel responsible for reducing their CO_2 emission from transport. The medium score was selected.
Geothermal Energy	
B1 Dependence other actors Scores: High, Medium, Medium, High	The high score is selected as the initiator of a project needs several permits and most likely a bank loan or a consortium to finance a project.
B3 Types of actors Scores: High, Medium, Low, Medium	The medium score is selected since most parties in the horticultural environment are positive about Geothermal Energy. Still quite some different actors are involved in the project (e.g. permitting authorities, constructors, local public, consortium)
D1 Awareness of actor Scores: Low, High, Low, Medium	Horticulturists are aware of the option do not know if it is viable for their terrain. The low score was chosen.
D2 Frequency of opportunity Scores: Medium, Low, Low/Medium, High	The medium score was chosen as several conditions were mentioned that must be met for an opportunity to arise, namely. sufficient capital, a positive result of geological research, ending of a gas contract.
D3 Behavioural change Scores: Low, High, Low/Medium, Medium/High	The medium score is chosen as an average as some interviewees said that some changes were needed in the day-to-day work such as measuring and small maintenance

C.2 Categorisation of types of interventions

The interventions which were mentioned by the interviewees are allocated (by the author) to the barrier they are aiming to affect. Some interventions are placed in the table twice as these as these affect more barriers. The type of interventions are categorised in sub-types of policy measures as defined by (van Zijl, 2017). The interventions have been marked in the three categories: Regulatory, Financial and Informative. Interventions shown in italics are *not (yet) in use or in development*, others are as concluded from the answers of the interviewees. The categorisation is shown in table C.2.1 and table C.2.2.

- R&D costs are categorised as financial interventions according to the used definitions
- Improvements of administrative processes (permit procedures) are placed under informative interventions
- The 'placing of a container to reduce noise' could not be categorised. This is a practical intervention.

From this categorisation the following conclusions can be drawn:

- It can be noticed that many barriers have a mix of the type of interventions (financial, regulatory or informative) which can influence them. Knowledge exchange on geothermal energy projects can, for instance, reduce the risk of projects (technological uncertainty C3) which makes it easier to finance these (A3, difficulty in financing).

- Many of the interventions for Carbon Capture Storage and Biofuels are not yet in use, while this is not the case for insulation. This relates to the adoption rate of biofuels and the current absence of CCS-projects in the Netherlands.

- Especially for insulation the focus is on informative interventions as it is the aim to reach a large group of households. For biofuels informative interventions are also relevant. The interventions of both abatement options show that it is challenging to provide an adequate solution to the household (with respect to their specific house or car). This makes it difficult to make a scalable intervention which takes these differences into account.

Table C.2.1 Categorisation interventions Carbon Capture Storage and Geothermal Energy

Factor	Carbon Capture Storage	Geothermal energy
A1. Investment costs	Technological research can result in cost reduction	SDE+-subsidy and 'garantiefonds' provide certainty for the investment for geothermal operators
		Research should be performed on risks, how to manage these risks and the costs of managing these, precautionary measures to keep the well function properly
A2. Payback period	*Minimum CO_2-price to strengthen business case*	SDE+-subsidy and 'garantiefonds' provide certainty for the investment for geothermal operators
A3. Financing investment	*EU-funding for demonstration projects*	*Projects with a high-quality execution can serve as showcases to increase trust of banks and public*
	Developing regulations on the subsidy scheme	Through knowledge exchange innovation can take place to reduce project costs, gain more stable production of the wells and increase safety of projects. Reducing the risk makes it easier to finance projects
B1. Dependence actors	*Acceleration of the permit procedure*	*Clarification of the responsibilities of parties involved, adequate regulation, policy and supervision should be developed for the sector*
	Development of a long-term vision from the government	*Adapting the permit procedure to shorten the procedure*
		Projects with a high-quality execution can serve as showcases to increase trust of banks and public
		Research and experience can increase the level of professionalism of involved parties
		Informative meetings aimed at local residents, 24/7 telephone number for questions, informative website on geothermal energy, newsletters
		In urban areas extra budget should be spent on providing information to local residents, installing 'geofoons' to register vibrations and making architectonic reviews of the condition of houses and buildings before drilling
B2. Number actors		

B3. Types actors	EU-funding for technical and social scientific research	Research and experience can increase the level of professionalism of involved parties
	Compensation scheme for local residents in case of CCS onshore	
B4. Responsibility division	*Developing regulations on responsibilities of different parties on the risks of CO_2 storage*	*Supply and demand should be matched to scale up geothermal energy. The government can be an organising party on this topic*
	Development of a long-term vision from the government	*Clarification of the responsibilities of parties involved, adequate regulation, policy and supervision should be developed for the sector*
		Research and experience can increase the level of professionalism of involved parties
C1. Physical embeddedness		
C2. Disturbs operation		Placing a container to reduce noise pollution
C3. Technological uncertainty	EU-funding for technical and social scientific research	*Research should be performed on risks, how to manage these risks and the costs of managing these, precautionary measures to keep the well function properly*
	EU-funding for demonstration projects	Gaining more experience in non-urban areas to prevent public resistance
	Knowledge exchange with different countries	Through knowledge exchange innovation can take place to reduce project costs, gain more stable production of the wells and increase safety of projects. Reducing the risk makes it easier to finance projects
D1. Awareness of actor		Informative meetings aimed at local residents, 24/7 telephone number for questions, informative website on geothermal energy, newsletters
D2. Frequency of opportunity	The Climate Agreement of Paris and the lawsuit of Urgenda create an urgency to take action	
D3. Behaviour change		

Table C.2.2 Categorisation interventions Insulation and Biofuels

Factor	Insulation	Biofuels
A1. Investment costs	Collective purchasing actions lead to a reduction in investment costs	
A2. Payback period	Real estate agents who can stimulate to insulate the home before selling it, instant return on investment	*Taxation of fuels related to their CO_2 intensity or through providing a financial reward for the reduced CO_2 emission to make the price more competitive with fossil fuels*
	Subsidies can reduce the payback period	*Subsidies to provide equal prices for biofuels and fossil fuels*
A3. Financing investment	Renovation stores and Energy Counters offer financing options	Strong long-term policy from the government is needed to provide parties certainty for investments in biofuel factories, for example shaped as an obligation to use biofuels
B1. Dependence actors	Renovation stores and Energy Counters offer independent advice, help with permit applications and overviews of different insulation options, asks for offers	Strong long-term policy from the government is needed to provide parties certainty for investments in biofuel factories, for example. shaped as an obligation to use biofuels
	Energy Cafés offer independent information	*Setting up a system of 'Guarantee of Origin' for Green Gas (Bio-CNG) to provide certainty about the availability*
		Offer a conversion kit for gasoline cars to car garages to make it possible to drive on E85-gasoline
		Gasoline stations must install a new pump and storage space for gasoline (E85)
		Expanding the regulation from EU with regard to biofuels
		One contact point for government from the biofuel sector for long-term consultation (platform)
		Stimulating cooperation and knowledge exchange in biofuel sector (platform)
B2. Number actors	Adapting the message to the type of households in a neighbourhood according to data about their attitudes towards life (e.g. prefers to have certainty, financial motivations)	*Setting up a mixed program to appeal to all car owners (diesel, gasoline, CNG) and thus provide customised advice*
		Setting up awareness campaigns focussed on behavioural change of consumers through developing a communication strategy
B3. Types actors	Adapting the message to the type of households in a neighbourhood according to data about their attitudes towards life (e.g. prefers to have certainty, financial motivations)	*Setting up a mixed program to appeal to all car owners (diesel, gasoline, CNG) and thus provide customised advice*
		Stimulating cooperation and knowledge exchange in biofuel sector (platform)

B.4 Responsibility division		
C1. Physical embeddedness		
C2. Disturbs operation		
C3. Technological uncertainty		Stimulating cooperation and knowledge exchange in biofuel sector (platform)
D1. Awareness of actor	Door-to-door approach to inform people	*Setting up awareness campaigns focussed on behavioural change of consumers through developing a communication strategy*
	Publishing articles on websites and in newspapers	
	Sustainable awareness campaigns of the government	
	Attention for climate change in mainstream media	
	Collective purchasing actions in neighbourhoods	
	Step-by-step guides to help households	
	Pop-up shops to inform people where heat pictures of homes in a neighbourhood were shown	
D2. Frequency of opportunity	Subsidies can create urgency	*Stimulating consumers to stick to green choices*
D3. Behaviour change		*Stimulating consumers to stick to green choices*

C.3 Grades analysis

The interviewees were asked to grade each barrier according to the extent to which this barrier is a hindrance to the materialisation of the abatement option. A large part of the interviewees had difficulty answering this question as they felt it did not differ much from the scoring of the barrier factor. The grades (see table C.3.1) showed quite some difference within the cases and between the interviewees in general, some picking extreme grades (10 and 1) others picking grades closer to each other. Therefore, some averages have a high and others have a low variance. The averages above 7 have been marked in green, averages below 5,5 have been marked in red. Links with the barrier scores can also be observed, as all abatement options showed financial barriers. Low grades are given to category C (physical interdependencies) as this category did not have many high barrier scores from the interviewees. It can be noted that the average score for D2 (frequency of opportunity) is high. Although this barrier was not clear to all interviewee, it does seem relevant after explanation.

Table C.3.1 Overview average grades on importance

Barriers	Insulation	Carbon Capture Storage	Biofuels	Geotherma l
A1. Investment costs	7,7	5,5	7	7,8
A2. Payback period	6,0	6,8	7	7,3
A3. Financing investment	5,7	7,8	8,5	7,0
B1. Dependence actors	4,0	9,0	5,5	7,3
B2. Number actors	8,7	5,3	4,5	4,5
B3. Types actors	6,0	7,0	4	4,3
B4. Responsibility unclear	3,0	8,3	5	4,8
C1. Physical embeddedness	6,0	5,0	5	3,3
C2. Disturbs operation	5,3	5,0	5	3,0
C3. Technological uncertainty	3,3	6,0	5	7,3
D1. Awareness of actor	8,7	5,0**	7	3,3
D2. Frequency of opportunity	3,7	8,8	8	7,7**
D3. Behavioural change	4,0	4,3	7	4,5
	n=3	n=4	n=2*	n=4

*One interviewee did not answer this question

** n=3 for this barrier

C.4 Comparing final barrier scores to case selection

In figure C.4.1 the barrier scores of all investigated abatement options are shown. Especially the first two categories show several high scores. Also some similarity in scoring can be observed for Carbon Capture Storage and Geothermal Energy as well as similarity can be seen in scores of Insulation and Biofuels. The latter two were, however, selected as ' most-different' cases. A reason for the similarity can be the additional scoping in the biofuel case on private car owners. This is group is similar to households, as most people own a house and a car and these posessions can have different physical characteristics. In Figure C.4.2 also much difference in the scoring for biofuels (in comparison to the input data) can be observed. The red dots indicate the different scores in this figure. The reason can be that the scoping of Chappin (2016) for this case was more on the poduction chain than on the private car owners.

In figure C.4.1 it can also be observed that no high scores are present in category C. If you compare this to figure C.4.2, many high scores are present. Many interviewees mentioned for barrier C1 that they included the visual aspect of physical embeddedness (change to the environment, C1) when evaluating it, which can be a reason for lower scores. The visual aspect is important, as this can influence how people perceive the change of environment quite much. However, it does not tell the full story of the 'technical' difficulty of an abatement project.

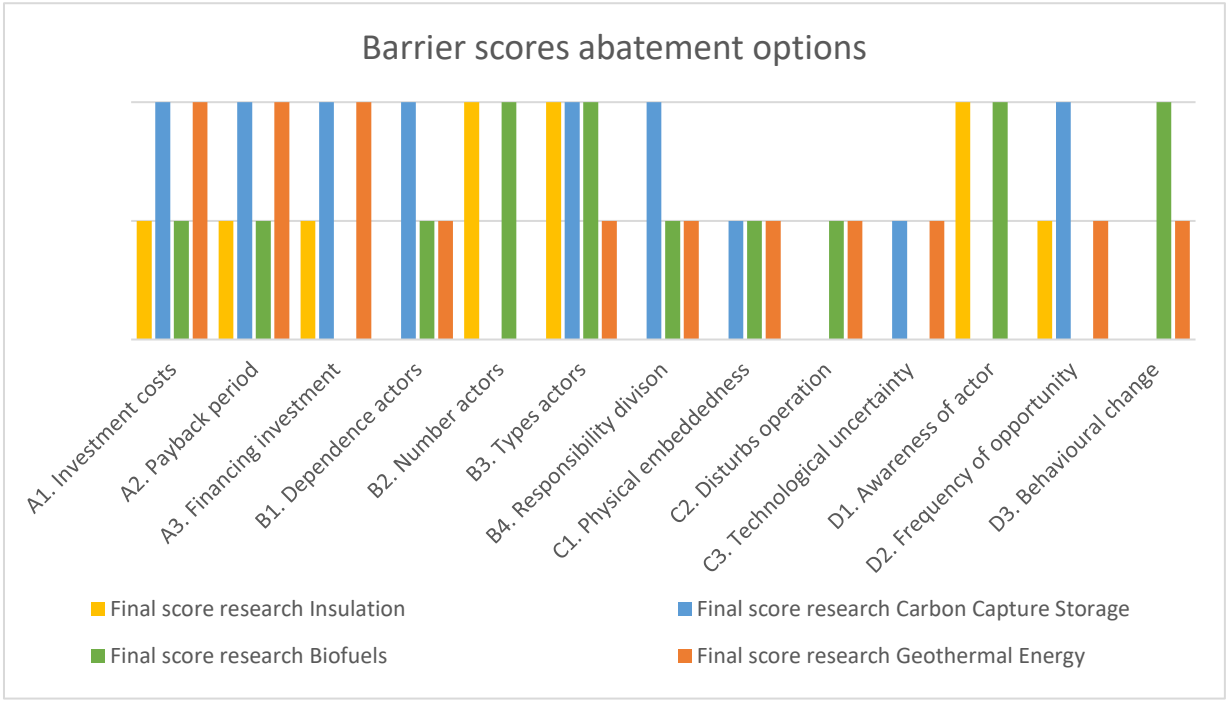

Figure C.4.1 Coverage barrier scores of four abatement options

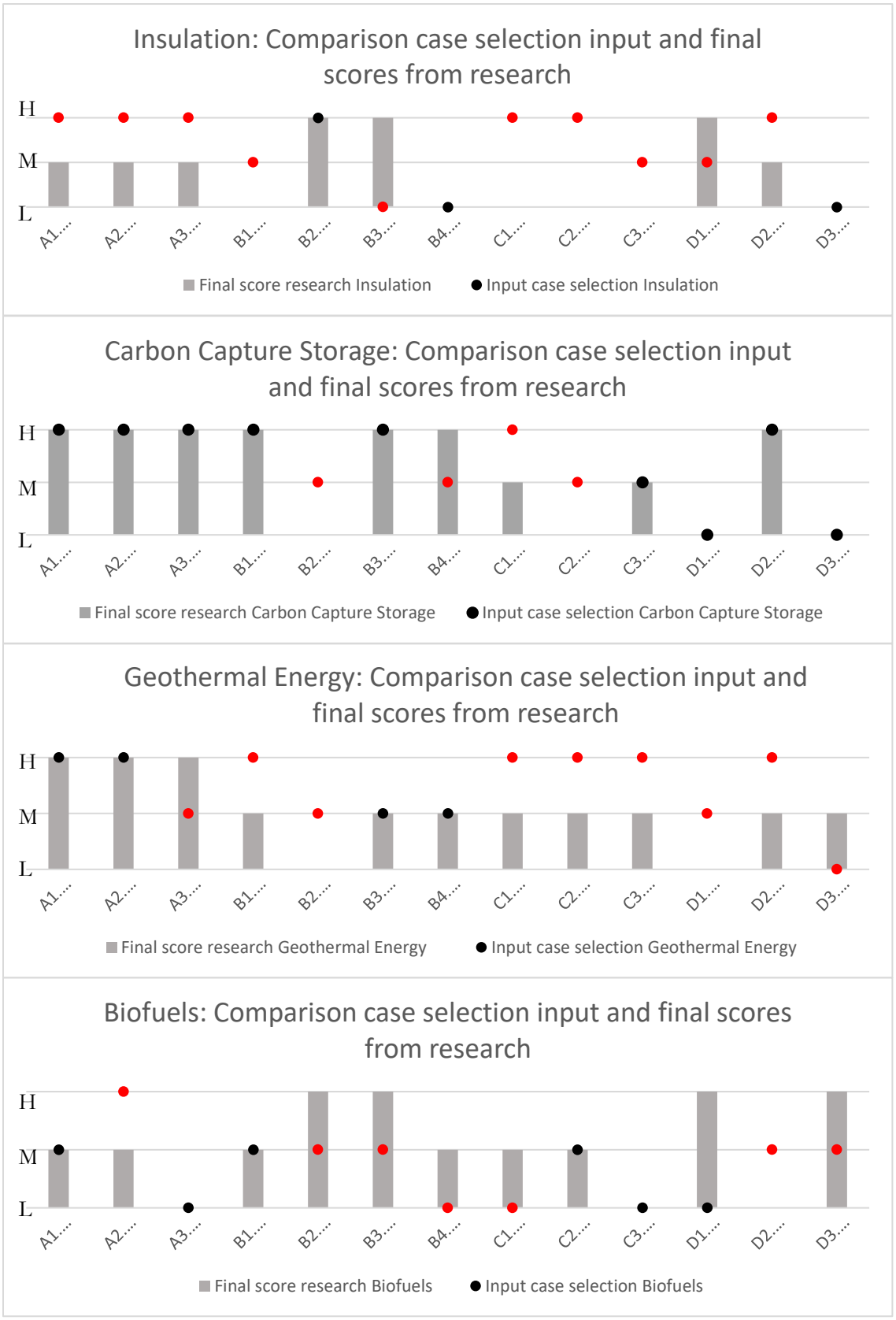

Figure C.4.2. Overview differences input barriers and barriers concluded from expert interviews

Appendix D: Y-factor definitions

Table D.1 shows the definitions of the Y-factor barriers that are used in this thesis. The definitions have been constructed by Chappin for his reordering of the MACC in (Chappin, 2016). The values 0, 1 and 2, that are shown in his original paper are replaced by low, medium and high in this research. The categories and their barriers have also been labeled with a code (A1..D3) to make it easier to refer to these elements. The high score of A2 is adapted from '>20 years' to '>12 years' to avoid unclarity in the expert interviews.The addition of 'skills' to B3 resulting from the literature review.

Table D.1 Y-factor including definitions

A. Costs and financing	**Low**	**Medium**	**High**
A.1 Investment cost required	Absent	Medium	Large
Degree to which the investment in an abatement measure is significant			
A.2 Expected pay-back time at 0 euro/ton	< 5 years	5-12 years	>12 years
Expected time required to earn back the investment for an abatement measure			
A.3 Difficulty in financing investment	None	Medium	Large
The degree to which it is difficult to finance the abatement or attract appropriate financial means			
B. Multi-actor complexity	**Low**	**Medium**	**High**
B.1 Dependence on other actors	None	Few	Many
Degree of dependence on actions of other actors to successfully implement and execute the abatement measure			
B.2 Number of actors	Few	Many	Millions
Number of actors that are required to take action to realise the abatement measure			
B.3 Types of actors involved	Few	Medium	Many
Degree of diversity of interests, values, roles, skills and expectations of the actors involved			
B.4 Responsibility unclear	Clear	Slightly	Unclear
The extent to which it is clear which actor has the responsibility for the abatement measure			
C. Physical interdependencies	**Low**	**Medium**	**High**
C.1 Physical embeddedness	No	Medium	Strongly
Degree to which the abatement measure requires physical changes to the environment it is placed in			
C.2 Disturbs regular operation	No	Slightly	Strongly
Degree (duration, intensity) to which status quo/regular operation is disrupted to successfully apply the abatement measure			
C.3 Technology uncertainty	Fully proven	Small	Large
Degree to which the technological performance of the abatement measure is uncertain			
D. Behaviour	**Low**	**Medium**	**High**
D.1 Outside of thinking scope of actor	No	Partly related	Outside scope
Degree of awareness of the parties responsible for the abatement measure			
D.2 Frequency of opportunity	Often	Medium	Rarely
Number of opportunities for the responsible party to realise the abatement measure			
D.3 Requires change in behaviour	No	Slight	Severe
Degree to which the actors involved need to change their day to day behavior			