MSc thesis in Complex Systems Engineering and Management

Facilitating the process of carbon abatement policymaking by exposing the complexities of GHG reduction

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TU Delft

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FACILITATING THE PROCESS OF CARBON ABATEMENT POLICYMAKING BY EXPOSING THE COMPLEXITIES OF GHG REDUCTION

Master thesis submitted to Delft University of Technology in partial fulfilment of the requirements for the degree of

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PREFACE

Before you is my graduation thesis; the final product of 5 months of intensive programming, conducting eye-opening interviews and seemingly endless writing. I really enjoyed applying the variety of skills that were needed for this project, which kept me motivated (most of the time) throughout this period.
Since my early days as a TPM student, I have always been intrigued by the challenges that the energy transition poses. I finished my bachelor with a study on local resistance to wind parks in the Netherlands and in the last few years, I have enjoyed putting the acquired knowledge into practice in order to stimulate my fellow students to participate in the energy transition. For me, this Y-factor graduation research has taught me a lot on the complexities of the energy transition and is the perfect ending to my time as a TU Delft student.

I would like to thank my supervisors for providing me support and guidance during my graduation.
Thank you Ivo, for your genuine and enthusiastic guidance. You challenged me from the kick-off meeting by expressing your slight concern for my programming skills, and with your spot-on comments on even the smallest details you helped me to take my thesis to a higher level.
Gerdien, in the last two years, I learned a lot from your expertise on the behavioural side of the energy transition and I have enjoyed working together on the social innovation platform. Thanks for providing the necessary outside perspective during my research!
Emile, thank you for being a critical, motivating and inspiring supervisor. Our meetings were very productive and kept me confident and full of energy. You very well managed to put my concerns in the right perspective, and seemed to have an answer (or new question) to all of my questions. Thank you for putting all the effort into reading my drafts, debugging the tool and supporting me along the way!

I want to express my gratitude towards my family for their support over the last months. Dad, thank you for your critical reading of my drafts and helping me to set up an interview! Also, thanks to my friends who proofread my thesis and provided me with some fine critics and red-marked pieces of text.
Josephine, thank you for the necessary distraction and support over the last months!

Enjoy the read!

EXECUTIVE SUMMARY

The exorbitant emissions of green house gases have put planet earth in a position with very worrisome perspectives. As a result of climate change, global temperatures are rising, just like the level of the oceans, putting the lives of many species at risk. The challenge of reversing the effects of climate change lies in the same hands as those of the ones that have been the cause of it: human beings. As the effects of climate change are no longer negligible, the realisation that we should be the ones to take action is finally settling with the most influential policymakers. However, the question of how to take the right action is for many still unanswerable. To facilitate policymakers, corporate leaders and academics with a structured approach on how to achieve emission reductions, marginal abatement cost curves (MACCs) have become widely used methods to assess different abatement opinions on its financial viability of implementation. These curves rank different abatement options on their associated marginal costs.

Marginal abatement costs curves, however, are often criticised for being too limited to explain the complexities hampering the implementation of abatement options. Policymakers are led to believe that the cheapest options are always the best options to realize. However, reality has proven different. In 2016, the Y-factor was developed as a complimentary approach to marginal cost curves, such as the McKinsey MACC (Naucler & Enkvist, 2009). The McKinsey MACC ranks carbon abatement options based on their marginal costs in € per ton CO_2 equivalent. The Y-factor complements these curves by providing abatement option-specific information on the complexities that are associated with its implementation.

The Y-factor was created to share insights into the barriers that hamper the implementation of abatement options. A set of 12 qualitative barriers was specified to cover the full range of implementation complexities. These barriers are spread across four categories; costs and financials, multi-actor complexities, physical interdependences and behaviour. Earlier research led to a validated Y-factor reference curve that ranks 24 different abatement options on their complexity of implementation.

The difference between the barriers addressed by the Y-factor and the MACC is that the barriers considered by the Y-factor are more qualitative and more dependent on contextual differences. As the barriers constituting the Y-factor are harder to grasp than marginal costs, more explanatory support for using the Y-factor is necessary too. Moreover, the application of the Y-factor curve in real-world situations has not yet been tested. Earlier research suggests that the Y-factor potentially is very useful for policymaking.

This complies with the initial purpose of the Y-factor: when first introduced, the Y-factor's goal was to provide new insights to policymakers. This notion, combined with the need for extra explanatory support constituted the re-

search objective to facilitate the applicability of the Y-factor for policymakers. This objective is supported by the following research question:

In what way can the Y-factor be enhanced to make it suitable for use by policymakers within the process of the policy cycle?

To structure the investigation on this research question, the policy cycle is used as a theoretical framework. This framework conceptualises the policymaking process in five stages: issue identification, policy formulation, decision-making, policy implementation and policy evaluation. The reason for choosing this framework is because its simplicity makes it widely applicable for evaluating policy processes and at the same time makes it easy to understand.

A comparison between the Y-factor and the specific characteristics of the stages of the policy cycle led to the conclusion that the Y-factor is mainly applicable in the stages of policy formulation and decision-making. This is because the Y-factor can serve as a high-level overview and function as a starting point for discussion to pinpoint the most relevant complexities that need to be addressed when developing policies. Moreover, the Y-factor consists of 12 different criteria, which facilitate the Y-factor's use for multi-criteria decision analyses (MCDA). MCDA's are very often used within the stage of decision-making. For the Y-factor to be suitable for policy implementation and evaluation, the Y-factor needs to be able to address more specificity regarding policy instruments, which it currently cannot provide. Figure 0.1 shows the possible application of the Y-factor for policymaking in light of the policy cycle.

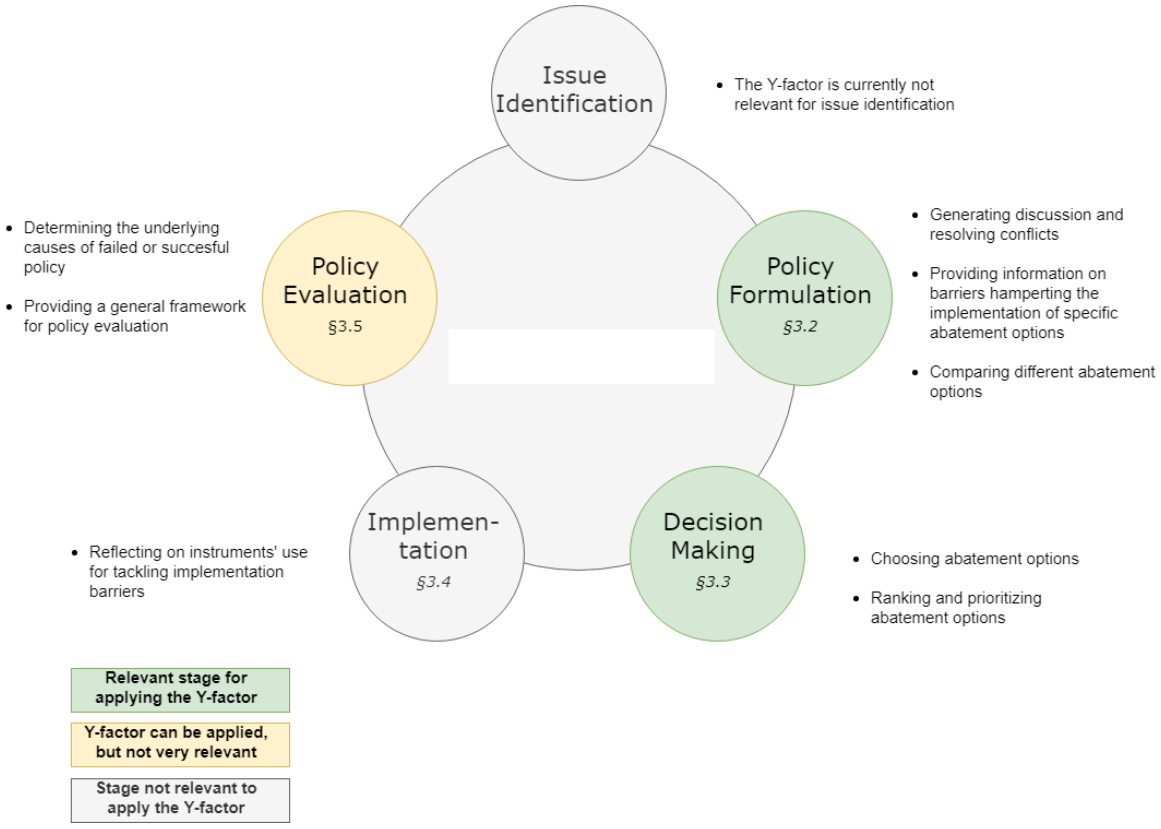

Figure 0.1: Application of the Y-factor within the policy cycle

To facilitate the use of the Y-factor for policymakers, a support tool is developed within this research to satisfy the following objectives:

- Assisting policymakers to use the Y-factor, whilst accounting for the context-dependency of the complexities that can hamper the implementation of carbon abatement options.
- Providing easier access to the information that determine the Y-factor barrier scores.
- Generating and facilitating discussions between policymakers.
- Illustrating the full implementation complexity of carbon abatement options, by facilitating a crossover graph of the McKinsey MACC and the Y-factor.

Based on these objectives, recommendations from earlier research and specifics deducted from the policy cycle analyses, a web-based tool is created using HTML and the Javascript-D3 library. These programming languages allow for dynamic visualisations and easy access to all internet browsers. Figure 0.2 shows an outline of the policy support tool. The tool consists of:

- The possibility to attach a relative weight to Y-factor barriers to indicate which barriers are comparatively harder to overcome than others.
- The possibility to change the abatement option-specific values (0,1 or 2) to account for different implementation complexities in the context of the policymaker.
- Checkboxes to show only the Y-factor values of the abatement options that are relevant for the policymaker.
- An interactive scatterplot graph, which shows the marginal abatement costs and the abatement potential from the McKinsey MAC-curve, and the cumulative Y-factor score.

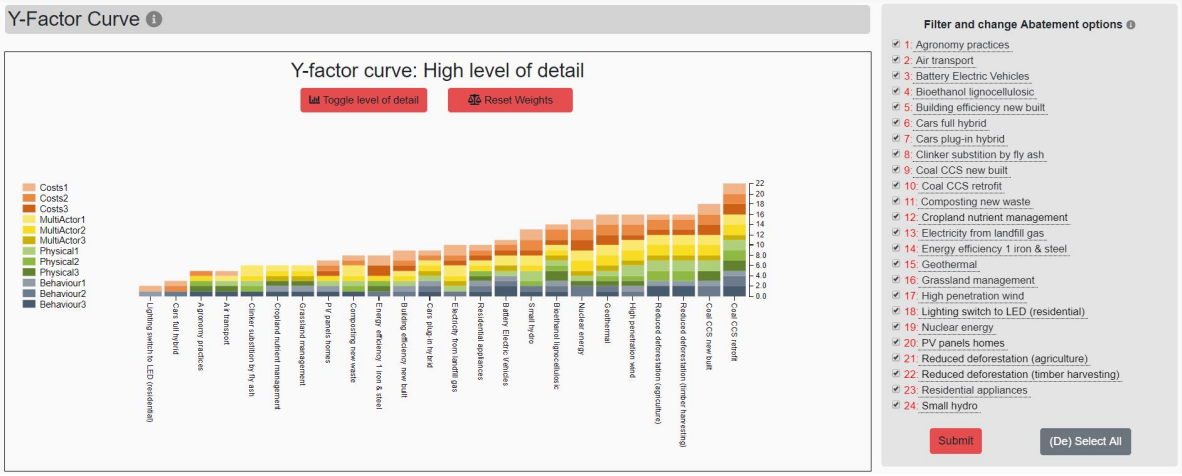

Figure 0.2: Y-factor policy support tool

To test the applicability of the Y-factor method and the Y-factor tool for policymaking, two focus groups and three semi-structured interviews were conducted. The focus group methodology allows for mimicking realistic policymaking situations. To do so, discussions were facilitated on three types

of situations for which the Y-factor tool could be applied. The group discussions were organised as such, that not only insights were generated from the things that were said, but also from the interaction that took place. The focus groups provided insights into how the Y-factor could be applied for policymaking and into how the tool could be improved, whereas the interviews were more helpful to generate insights into how policymaking processes are currently taking place and into whether the employees envisioned the Y-factor to have added value for these processes.

The interviewed policymakers expressed their interest for the Y-factor and, most of them, regarded it as a suitable tool for policymaking. Although there is an increasing awareness that the choice for options to reduce GHG emissions cannot be solely built upon financial considerations, the policymakers acknowledged that there is currently no suitable alternative that incorporates more aspects. The Y-factor could become a respectable method to provide an integral and structured way to assess carbon abatement options.

The Y-factor showed the potential to present a high-level overview indicating the implementation complexity of a wide range of abatement options. It was recognised that this overview is suitable as a starting point for policy discussions, and with this confirmed the Y-factor's predominant suitability for formulating policies. The policymakers advised to construct reference scores and reference Y-factor curves on a national level. The reason given, is that the majority of carbon abatement policies are formulated on a national level, and moreover, most of the considered complexities are very context-specific. They are context-specific in the sense that laws and regulations are often determined on a national level, and that the organisation in terms of involved actors are too. Apart from the Y-factor's suitability as a reference curve, its application for generating structured discussions was highlighted as well.

The Y-factor tool can be employed for three different activities: educating policymakers, facilitating discussions and developing new Y-factor reference curves. The objectives of the three activities are different and to satisfy these objectives, the tool should be used accordingly. The main objective for educating policymakers is to help them understand the implementation complexities of abatement options. This activity should be preceded by an explanation or a the consult of a manual to ensure the correct use of the Y-factor tool. For the facilitating of discussions, the Y-factor tool can be used to pinpoint differences in beliefs between actors and to structure their argumentation. These discussions will be most effective when moderated by someone with Y-factor expertise. The development of reference curves should be executed by experts and need to be well substantiated. Reference curves can be created as national reference curves or as organisation-specific curves.

To conclude, the use of the Y-factor is facilitated with the development of a support tool. This tool was appreciated by policymakers for generating insights during the early stages of the policymaking process. To create more value, it is advised to pursue the validation of more abatement options to ensure an even wider applicability of the tool. Moreover, the Y-factor could

potentially become even more reliable when reference curves on a national level are created. With regards to applications in other disciplines, it is worthwhile investigating the use of the Y-factor for educational purposes and for determining investment strategies in the private sector.

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1 Introduction

In October 2018, the International Panel on Climate Change (IPCC) released a document with different scenarios, which reveal the urgency to tackle climate change at a faster pace, in order to avoid irreversible damage. An increase of more than 1.5 degrees Celsius would mean that the Earth's atmosphere would become unstable, that CO2-levels would become uncontrollable, and consequently, the temperatures would rise even further (IPCC, 2018). Unfortunately, these scenarios are very real and carbon emissions will reach an all-time high again in 2018 having risen with 2.0% since 2017 (Le Quere et al., 2018).

Many developed countries have already reached their peak emissions, but there are still many countries, which will not reach its peak in the near future. During COP21, often referred to as the Paris Agreement, strict targets for each country were formulated to reduce emissions. The Netherlands has been challenged with the elimination of 49% of its greenhouse gas (GHG) emissions in 2030 relative to 1990 (United Nations, 2015). The most important GHG is CO2 and therefore many technologies and policies are developed and institutions set up to reduce the emissions of CO2 and adhere to the goals set in the 2015 Paris agreement. The urgency has challenged both private and public entities but also demands more research and development. Among academics, there is increasing attention on how to shift towards a more sustainable future in the field of energy.

1.1 Multi-factor complexity of the energy transition

Although, after fierce debates, climate change is finally recognised as an imminent threat by the general public, it complicated to be able to transit from conventional systems as they are often deeply embedded in political, social, economic and institutional society (Lachman, 2013). An evaluation of important transition theories reveals that many theories provide interesting concepts on how to facilitate sustainable change, but that it remains very hard to put it in to practice, due to different contexts (Lachman, 2013). In an analysis of the transition of the Dutch Energy sector, it was found that through the layering of transition reforms – when new goals and policies are layered upon existing ones- the alignment of different policy goals and instruments proved very difficult (Kern & Howlett, 2009). Policy interventions towards sustainability often had conflicting short-term and long-term goals which show the challenge of successful transition management.

To facilitate a transition towards fewer emissions of GHGs in the Netherlands, there are many different carbon abatement options that could contribute. To come to a decision on which abatement option to choose for or invest in is challenging, due to many different considerations that need to be made. On a national level, many organisations are forced to collaborate, which does not only lead to slower decision-making but also to the interference of policies on the same sectors (van Zijl, 2017). On a lower level, the factors and considerations leading to investors' pick for renewable energy (RE) investments are affected by their preferences over policy instruments (e.g. feed-in tariffs), a priori beliefs and attitude towards associated risks (Masini & Menichetti, 2012). The mentioned researches by Van Zijl and Masini & Menichetti mention the challenges of decision-making for the energy transition. However, it does not yet provide guidelines or a theory that qualifies what carbon abatement option is to be prioritised in which particular situation.

A report by McKinsey&Company (Naucler & Enkvist, 2009) provides a guideline by using a Marginal Abatement Cost Curve (MACC), which prioritises carbon abatement options on its associated marginal costs. This economic way to look at investments to reduce carbon emissions has long been leading in literature, public and private sector but is now more often contested. It is claimed that technologies should not only be looked upon by marginal costs but that the associated benefits need to be taken into account too (Ward, 2014) or that a longer-term vision should be adopted as cheap, short-term solutions arriving from the MACC are not always most viable (Vogt-Schilb & Hallegatte, 2014). Other arguments against MACC suitability for prioritising carbon abatement technologies state that behavioural aspects, technological issues and uncertainties are overlooked by only taking into account marginal costs (Kesicki & Ekins, 2012). The latter arguments have been the main driver for Emile Chappin to develop a new qualifying method; the Y-factor (Chappin, 2016).

1.2 Y-FACTOR

The Y-factor distinguishes four categories on which carbon abatement options can be assessed to understand why abatement options may or may not be hard to realise. These categories are costs and financing, multi-actor complexity, physical interdependences and behaviour. These categories are further specified in twelve socio-technical barriers (three barriers per category) that collectively determine the Y-factor score for a carbon abatement technology. Each of the Y-factor barriers is to be scored on a tripartite scale (0,1 or 2). The explanation of the scores differs per barrier, as a majority of the criteria has a qualitative nature. Figure 1.1 shows the categories, barriers and values of the Y-factor.
The scores on these twelve Y-factor barriers are summed to give insight into the combined complexities of implementation, and consecutively compare it with other carbon abatement options. It must be noted that the criteria are qualitative and therefore, a comparison between carbon abatement options

Category	Factor	Value 0	Value 1	Value 2	Definition
(A) Costs and Financing	Investment cost required (A1)	Absent	Medium	Large	Degree to which the investment in an abatement measure is significant
	Expected pay-back time (A2)	<5 Years	5-12 years	>12 years	Expected time required to earn back the investment for an abatement measure
	Difficulty in financing investment (A3)	Low	Medium	High	The degree to which it is difficult to finance the abatement or attract appropriate financial means
(B) Multi-actor Complexity	Dependence on other actors (B1)	No	Little	Much	Degree of dependence on actions of other actors to successfully implement and execute the abatement measure
	Diversity of actors involved inc. conflicts (B2)	Low	Medium	Large	Degree of diversity of interests, values, roles, skills and expectations of the actors involved. Degree of public acceptance. When opposing interests from the (local) public to the implementation or the abatement option are (expected to be) present, a high score should be given.
	Division of roles and responsibilities unclear (B3)	Clear	Slightly	Unclear	The extent to which the roles and responsibilities for the realization of the abatement option are clear
(C) Physical Interdependences	Physical embededdness (C1)	No	Medium	High	Degree to which the abatement measure requires physical changes to the environment it is placed in
	Disturbs regular operation (C2)	No	Slightly	Strongly	Degree (duration, intensity) to which status quo/regular operation is disrupted to successfully apply the abatement measure
	Technology uncertainty (C3)	Fully proven	Small	Large	Degree to which the technological performance of the abatement measure is uncertain
(D) Behavior	Absence of knowledge of actor (D1)	High Knowledge	Low Knowledge	No Knowledge	Level of knowledge of the parties responsible for the abatement measure
	Frequency of opportunity (D2)	Often	Medium	Rarely	Number of opportunities for the responsible party to realize the abatement measure
	Requires change in behavior (D3)	No	Slight	Severe	Degree to which the actors involved need to change their day to day behavior

Figure 1.1: The Y-factor (Soana, 2018)

based on the Y-factor scores, must be approached carefully. A value of 2 on required investment costs (A1) cannot be automatically seen as similar to a value of 2 on a required change in behaviour (D3).

Preliminary results of the Y-factor analysis differ significantly from the results generated by the MACC. Taking into account more indicators than marginal costs, the Y-factor results into a broader perception of the difficulties that hamper the reduction of GHG emissions.

1.3 Previous Y-factor research

In 2016, the Y-factor was first introduced as a complementary approach to the McKinsey MACC (Chappin, 2016). The Y-factor consisted of 13 barriers (the Multi-Actor Complexity category existed out of 4 sub-factors instead of 3) that were used to rank the 50 carbon abatement options that are also present in the McKinsey curve. The scores linked to these barriers were preliminary but were used to give an idea of how the Y-factor could best be applied.

Arensman (2018) continued the Y-factor research with a comparison of the Y-factor research method and IPCC reports to analyse how the Y-factor barriers were integrated into the IPCC report and how these barriers could be further specified and clarified. This research led to a refined Y-factor method, with the removal of the 13th Y-factor barrier, and an improved specification of the barriers. Moreover, four different carbon abatement options were selected to be assessed with the Y-factor. Subsequently, the Y-factor was applied in expert interviews to link scores to the Y-factor barriers.

Cheung (2018) aimed to support the Y-factor from the perspective of the theoretical concept of transition theory. He concluded that mainly the multi-actor complexity category finds its backing in this theory as it has the best fit with empirical data. Like Arensman, Cheung conducted expert interviews (21) to test score carbon abatement options on the Y-factor.

Despite some remarks about the possible bias of interviewees and the difference of opinion on the Y-factor barrier scores, Arensman and Cheung showed that the Y-factor is a suitable research method to evaluate carbon abatement options for implementation. Soana (2018) continued the research where they left off with the intention to develop an emission abatement curve that captures all Y-factor implementation barriers. He made a selection of 24 abatement options, based on the options considered by the MACC-curve whilst ensuring a spread across sectors and a range of expected Y-values (based on Chappins preliminary scores).

These 24 options were given preliminary scores based on Soana's own estimation from literature. Consequently, these scores were validated in different expert interviews to construct a validated Y-factor emission curve. A simplified version is shown in figure 1.2. It must be noted that this curve should be seen as a reference curve. The barriers of the Y-factor are inherently context-specific, and throughout expert interviews, the difference of opinions shows that there is not one single emission curve that fully manages to explain the barriers to implementation of carbon abatement options.

After the development of the reference curve, experts on emission curves from the Ministry of Economic Affairs, PBL and ECOFYS were introduced to the Y-factor and confronted with the question of how they would envision the Y-factor to be applied. The Y-factor was mentioned as valid and insightful, but the envisioned applications of the Y-factor differed strongly across the interviewed energy strategists. Soana (2018) concludes with the remark that the Y-factor can be employed for three different activities: support to policy-making, support to research analyses and support to business strategies.

1.4 Knowledge gap

The Y-factor facilitates the comparison of different carbon abatement options and the identification of barriers to implementation of these options. Therefore, the Y-factor could be used on a very broad level (what Renewable Energy technology should the Dutch government subsidise?), but also on a more specific level (if a company wants to invest in wind energy on the sea, what potential friction could it expect on a behavioural level?). Soana (2018) reveals that the Y-factor can be employed for three activities: support to business strategies, support to researches and support to policy-making. However, how the Y-factor could best be applied for these three activities has not yet been investigated.

For business strategies, the Y-factor could help with the strategic allocation of available resources, the investigation of the most interesting products or

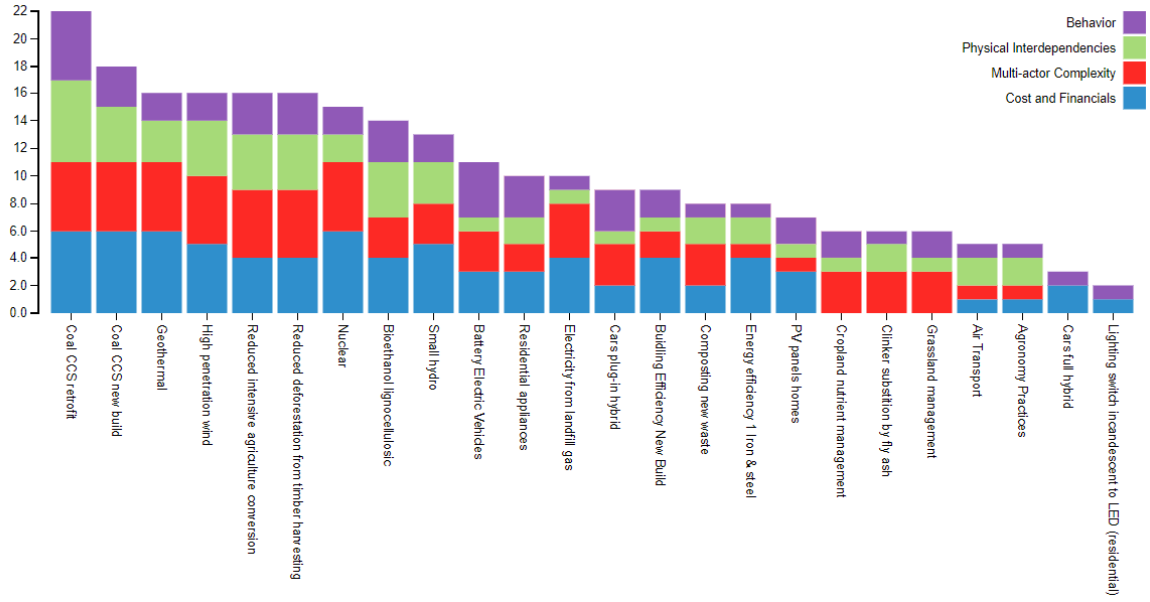

Figure 1.2: Y-factor emission curve

services for investment and the pinpointing of existing implementation barriers. In the field of research, the Y-factor allows for the comparison of different opinions on implementation barriers and enables the construction of new tools combining quantitative and qualitative insights on abatement options (Soana, 2018). The Y-factor could potentially support policymaking by fostering the discussion on the policy measures that could be implemented to tackle implementation barriers. Furthermore, it facilitates the comparison of policies belonging to different domains.

As was addressed earlier, policies are often prone to interference across sectors or different policy interventions (van Zijl, 2017). Moreover, the lack of stable institutions that stimulate renewable energy technologies and the poor alignment of these institutions with other sectors, combined with lack of technological knowledge has led to weak policy intervention in the past (Negro, Alkemade & Hekkert, 2012). A successful policy is to be established by assessing the specific requirements related to the technology, financial resources, network of actors and distance to market (Negro et al., 2012). This claim supports the effort to see whether and how the Y-factor might be suitable to formulate and assess policy interventions.

1.5 Research question

The Y-factor is regarded as a potentially successful way to analyse and compare carbon abatement options. For its practical applicability, more testing within different fields is needed to prove its value. This research focuses on how to make the Y-factor applicable for policymakers. Can the Y-factor help to determine the most suitable policy interventions, and how can the Y-factor contribute to facilitating structured decision making on

carbon abatement policymaking? By using the policy cycle as a theoretical framework, the Y-factor is presented and modified in a way to support policymakers. The following research question summarises the academic challenge and helps to structure this research:

In what way can the Y-factor be enhanced to make it suitable for use by policymakers within the process of the policy cycle?

This research question is supported by the following five sub questions, which are discussed in more detail in chapter 2:

1. "In what stages of the policy cycle can the Y-factor be applied?"
2. "How can the Y-factor be made more accessible and facilitated in use for policymakers?"
3. "How can the applicability of the Y-factor tool for carbon abatement policymaking be tested in focus groups?"
4. "How do policymakers value the contribution of the Y-factor for carbon abatement policymaking?"

1.5.1 Scientific contribution

With the establishment of a reference Y-factor emission curve, the theoretical validation of the Y-factor reached a final stage. The initial purpose of the Y-factor was to be an effective tool for policymakers. This research tests the applicability of the Y-factor in the policy arena in a scientifically relevant way. Thus far, the optimal use of the Y-factor as a policymaking tool has only been speculated about in expert interviews. Using these interviews, supported by the theoretical framework of the policy cycle, an assessment is made on how to integrate the Y-factor into the policymaking process. By facilitating structured focus groups, the practical applicability of the Y-factor in the policy arena is observed and tested for its usefulness.

1.5.2 Societal relevance

Climate change is often seen as a wicked problem, as it inherits deep uncertainties, economic consequences and even a lack of agreement on what the exact problem is. Due to the many different factors to take into account when formulating and implementing policies, the policymaking process on climate change is often unstructured and slow. The intention of the Y-factor is to structure these policymaking processes. This research tests the applicability of the Y-factor within these processes and consequently helps to assist in the societal issue of solving the wicked climate change problem.

1.5.3 Fit with CoSEM objectives

The Master Programme of Complex Systems Engineering and Management focuses on design within a socio-technical environment. The Y-factor itself inherits a socio-technical nature as it assesses the suitability of carbon abatement options on four different categories, ranging from physical implementation to behavioural implications. Therefore, this Y-factor research constitutes a natural fit with the CoSEM programme.

More specifically, this thesis research has a link with design in the socio-technical environment too. One of the core components in the CoSEM programme is to account for different opinions within decision making processes. With the design of a supporting tool, and mimicking real-world policymaking situations, this research works towards a solution design to improve complex decision-making processes in a socio-technical environment.

2 Research Approach

This chapter proposes a methodology on how the research will be organised to provide answers to the main research question. First, the design approach is specified, after which sub-questions are established to granulate the main research question and finally, the research approach is visualised in a flow diagram.

2.1 Introduction

Earlier Y-factor research employed expert discussions on the applicability of the Y-factor for drafting energy strategies in the Netherlands. The approached experts mentioned the lack of easy implementation as a limitation of the Y-factor, due to its relative complexity as compared to McKinsey's MACC. Soana (2018) states that the Y-factor scores need more validation for several carbon abatement options. Furthermore, the interviewed experts mention that the large number of different factors that are included in the Y-factor may also lead to a larger margin of error and lower associated validity. However, if validity could be improved and complexity reduced, then experts confirm the potential of the Y-factor in policymaking.

The results found by Soana that are mentioned in the previous paragraph demand for further research. An investigation for finding a way to reduce the complexity of the Y-factor for wider application is recommended and consecutively, suggestions can be made on how the Y-factor can contribute to policymaking. The next paragraphs will propose a design approach to continue this research.

2.2 Research approach

The main objective of this research is to test if and how the Y-factor can be applied as a method to support policymaking. This sub-chapter will explain how this research will be structured in order to fulfil this objective. First, the three most important components of this research will be introduced; the policy cycle as a theoretical framework, the focus group research method and the proposed tool to make the Y-factor more visually and interactively applicable. These three components are dependent on each other, which will be elaborated afterwards. The third part of this research approach por-

trays the intended structure of the final document, which is also visually supported by a research flow diagram.

2.2.1 Components Y-factor research

Within this research, three important building blocks can be identified; the policy cycle, the Y-factor (as a software tool) and the focus group research method. These components are closely linked, as choices made in one will have implications for the design of the other two components. The policy cycle will be used as a theoretical framework in which is to be tested how the Y-factor could be applied in the policy arena, by setting up focus group discussions. For example, if based on the policy cycle literature review, the conclusion is drawn that the Y-factor is sole of use in the decision-making stage of the policy cycle, this has implications for the setup of the Y-factor tool and the to be discussed topics in the focus group.

2.2.2 Thesis structure

This section lays out the structure of the document. The components mentioned in paragraph 2.2.1 collectively constitute the basis for meeting the objectives of this research. Below, the different chapters, their sub-questions and supporting methodology will be discussed after which this is shown in a flow diagram.

Chapter 3: The policy cycle

Thus far, the Y-factor research has mainly focused on construction and validation of the Y-factor barriers, linking the Y-factor to transition theory and construction of the Y-factor curve. This thesis will focus on how the validated Y-factor curve can be supportive for decision-makers in the policy arena. The policy cycle is one of the most widely used theoretical concepts when it comes to understanding the different processes that take place in policymaking. This cycle identifies five stages that policymakers go through when developing new policies (issue identification, policy formulation, decision making, implementation and evaluation).
Within this chapter, the objective is to identify in what stage or stages of the policy cycle the Y-factor could potentially be applied.

Sub-question 1: "Where does the Y-factor fit within the policy cycle?"

Methodology: A literature review will be conducted to generate insights into the characteristics of the different phases of the policy cycle and into how comparable tools were integrated into the policy cycle.
Based on this literature review, an analysis is carried out to determine how the Y-factor could fit in the policy cycle in its current form. Furthermore, requirements are defined on how to add upon and improve the Y-factor to widen its applicability to other stages of the policy cycle.

Output: Conclusions on the current applicability of the Y-factor within the policy cycle and possible limitations of the Y-factor within this framework. These conclusions are to be translated into requirements for the development of the Y-factor supporting tool (Chapter 4).

Chapter 4: Y-factor tool

A core part of the thesis research is founded on the development of a tool, which visualises the Y-factor, gives it dynamic functionalities to weigh different carbon abatement options and makes it easy to use for integration within the policy cycle. The design and creation of the tool are built upon the requirements that were formulated in Chapter 3 and previous research that established the wish for better visualisation of the Y-factor.

Sub-question 2: "How can the Y-factor be made more accessible and facilitated in use for policymakers?"

Methodology: The main function of the tool is to dynamically make use of the Y-factor and provide data visualisation to support policymakers. D3.js is a JavaScript library that is open source, widely used and renowned for its ease of use, visualisation capabilities and dynamic applicability (Zhu, 2013) and will, therefore, be used. These visualisations are stored within an HTML environment.
Output: A tool that can visualise the Y-factor and can dynamically provide information for policymakers.

Chapter 5: Focus Group and Interview Design

This chapter will focus on how the Y-factor (tool) can be tested for its applicability as a support in the policymaking process. This chapter establishes the methodology that is central to this research. The detailed setup of this methodology is dependent on the choices that are made in chapters 3 and 4.

There are several research methods that could possibly be conducted to test the tool that will be described in chapter 4. Below, multiple case studies are presented that tested similar tools. The selection of these case studies is limited to qualitative research methods involving multiple participants.

Adagha, Levy, Carpendale, Gates and Lindquist (2017) investigated whether a wind farm placement planning tool lives up to the sociotechnical requirements of stakeholders in the state of Alberta, Canada. This study was conducted by using multiple focus groups to simulate real-world perspectives and test if the policy support tool was comprehensive and easy to use. These focus groups generated insights into barriers that influence acceptance and use of the tool, and on how stakeholders currently interact with planning tools in general. The stakeholders filled out a questionnaire after the focus groups, to state their opinions on the tool and the focus

group they participated in.

Battleson, Booth and Weintrop (2001) tested the usability of a website on similar criteria as mentioned in the previous paragraph. They mention that "Interviews and focus groups are structured methods of inquiry which are used to gather information about user experiences and preferences. While surveys and questionnaires may also be used to gather such information, interviews and focus groups allow for more interaction with the users and for immediate answers to questions raised during the interview or focus group". Furthermore, they mention that the advantage of using focus groups allows for interaction with the users. Questionnaires and surveys become more relevant in a later stage of development of a product.

Isenberg, Zuk, Collins and Carpendale (2008) conducted a study on how to evaluate information visualisation. A conclusion from this study is that qualitative studies are more relevant to gain a rich understanding of the factors that influence information visualisation use, which might in the design phase be more relevant than statistical data.

The development of the Y-factor tool is predominantly based on previous research and an investigation into the stages of the policy cycle. However, the tool itself still needs to be tested by potential users. A conclusion that can be drawn from earlier research on the evaluation of similar tools is that qualitative research is more relevant than quantitative research in the early stages of the tool development. This is because qualitative research can provide more detailed feedback on the tool, which helps to refine requirements or develop additional features. There are multiple types of qualitative methods that could be successful for testing the Y-factor tool. Due to the tool's final objective to generate discussion between policymakers, a qualitative research method, which allows for multiple participants is beneficial. Using focus groups complies best for the assessment of the tool. The research by Adagha et al. (2017) shows many similarities with the Y-factor tool research and is a successful benchmark on how to conduct a focus group to test a policy support tool.

Chapter 5 works towards establishing how focus groups can provide optimal testing circumstances to evaluate the applicability of the Y-factor curve in the policy arena. Focus groups can generate discussions on predefined questions or case material concerning the usefulness of the support tool in policymaking. These group dynamics can, therefore, generate different results than a one-on-one interview would. The other main reason for choosing focus groups as a research method is because it more naturally provides the possibility to recreate real-world situations. Within focus groups, multiple policymakers are to be brought together to discuss relevant carbon abatement policy challenges and will be presented the Y-factor as possible support in this process. Within chapter 5, the ideal structure of the focus group will be excogitated in terms of which

participants are preferred, specific time planning, predefined questions and possible outcomes. Furthermore, a small part will also be dedicated to the use of semi-structured interviews, which were conducted as a result of not being able to get everyone together for a focus group.

Sub-question 3: "How can the applicability of the Y-factor tool for carbon abatement policymaking be tested in focus groups?"

Methodology: An analysis on the most effective way to set up focus groups in order to test the Y- factor tool in real-world situations.
Output:Intended focus group setup, in terms of participants, case material and envisioned results

Chapter 6: Results

This chapter will present the test results on the applicability of the Y-factor in the policy arena. Evaluations by focus group participants on the Y-factor (tool) and its applicability in the policy arena will be presented in this chapter. Specifically, results can be found on whether the policy support tool manages to fulfil its intended purpose. Eventually, this assessment leads to conclusions and recommendations for further research.

Sub-question 4: "How do policymakers value the contribution of the Y-factor (tool) for carbon abatement policymaking?"

Methodology: The focus group will be held according to the setup from Chapter 5. To quantify expert opinions and preferences, a questionnaire will be held afterwards.
Tool: NVivo is a tool that can help to structure information extracted from qualitative research methods such as semi-structured interviews and focus groups. SPSS will be used to analyse the results from the questionnaire evaluating the focus group.

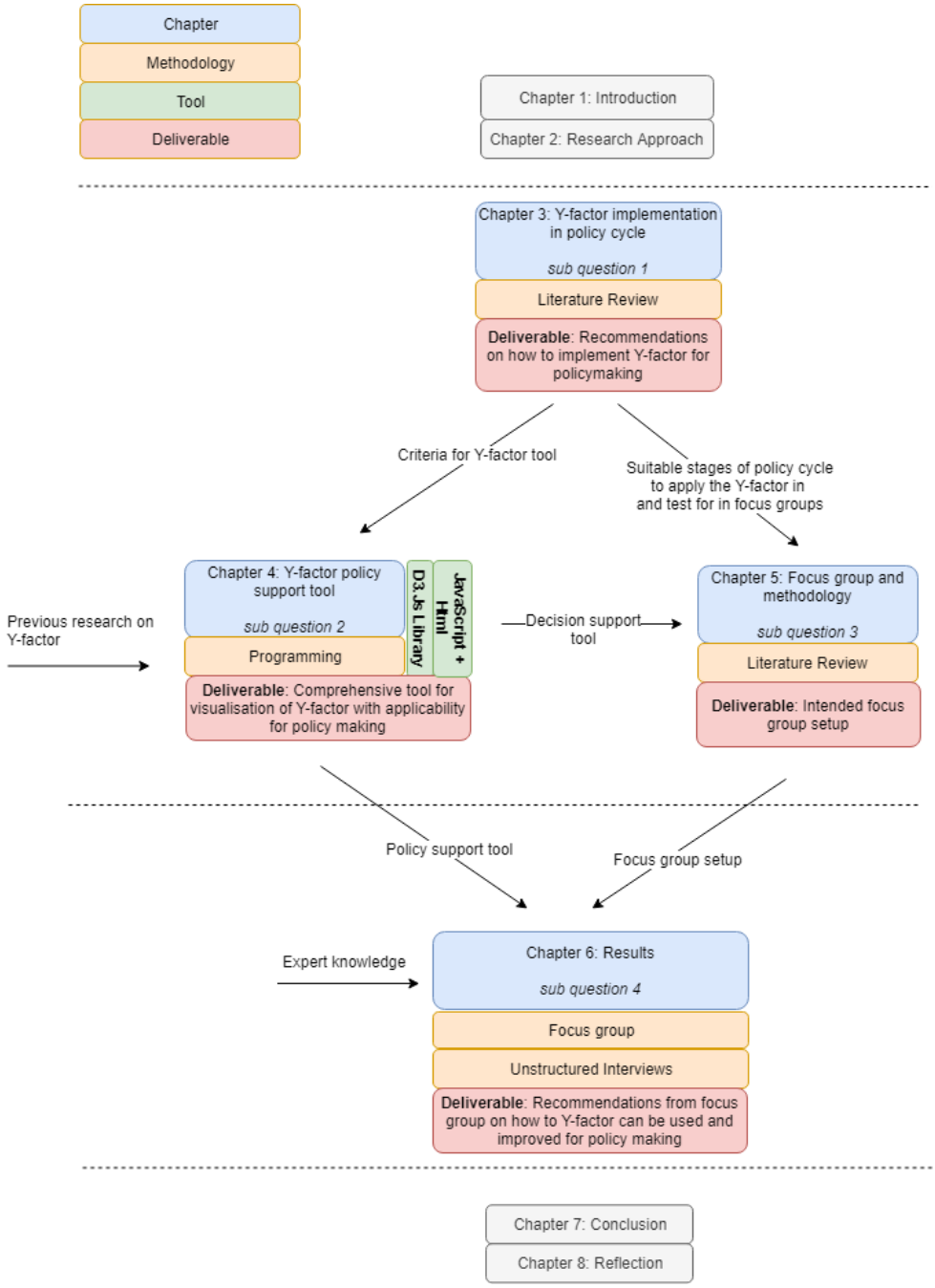

Figure 2.1: Research Flow Diagram

3 Policy Cycle

3.1 Introduction

The policymaking process is a complicated process, which has for decades been debated and explained by many different theories and frameworks. Of all the theories used to define policymaking processes, the policy cycle is one of the oldest, and most used in academic literature (Dye, 1992). The framework was first introduced by Lasswell in 1951 (Lerner & Lasswell, 1951). Contrary to other widely used approaches like the multiple streams model and the advocacy coalition framework, the policy cycle is a more simplified representation of the policy process. The policy cycle breaks down policymaking into different stages. These stages help to describe the process from problem identification to policy evaluation. The simplicity of this representation has led to it both being utilised and criticised a lot (Mwije, 2013). Critics state that the policy cycle is unrealistic, due to its linear approach, its lack of incorporation of messy decision-making processes and lack of acknowledgement of the irrational behaviour of actors (Mwije, 2013).
However, since its introduction, researchers have continued using the policy cycle as a theoretical framework to better understand the process of developing policies (Dye, 1992). As the policymaking process is broken down into a number of stages and sub-stages, and each stage can be investigated on its own, the process is made very comprehensible and therefore applicable for many different analyses (Howlett & Ramesh, 2003).
This chapter first explains why the policy cycle is used as a framework to analyse the Y-factor applicability for policymaking. Hereafter, each phase of the policy cycle is discussed in more depth, and the possible application of the Y-factor within each of these phases is investigated. The objective of this chapter is to give a clear overview of the possibilities that the Y-factor could offer policymakers and to translate these into requirements for the policy support tool, which is discussed in Chapter 4. This is done by answering the following research question: *In what stages of the policy cycle can the Y-factor be applied?*

3.1.1 The policy cycle as a framework for introducing the Y-factor to the policy arena

The policy cycle shows a sequenced policy process in a cyclic from, as it assumes a recurrent process that is not necessarily finished after a stage of evaluation (Howlett & Ramesh, 2003). It approaches the policymaking process from a high-level perspective, making it possible to analyse nearly

every policy process (Howard, 2005). The policy cycle originally has five major stages: problem identification, policy formulation, policy decision-making, policy implementation and policy evaluation (Howlett & Ramesh, 2003). Some scholars identify extra stages in between the existing stages, such as a monitoring stage before evaluation, or a termination stage after evaluation.
The policy cycle is, in some cases, specifically altered to the characteristics of certain sectors, by further specification of existing stages or the addition of stages that help to explain the processes within the sector. The Y-factor has a very broad scope and stretches across different sectors and areas of expertise. Altered versions of the policy cycle that are specifically adjusted to sectors, can not be applied one-on-one in this research. Therefore, the traditional approach of the policy cycle with five stages is used as a framework in this research.
The wide applicability of the Y-factor and its current lack of practical experience in the policy arena are the main motives to use the policy cycle as a framework to test the applicability of the Y-factor in the policy arena.

3.1.2 Overview of policy cycle stages

A common understanding for almost all scholars is that the first step of the cycle is issue identification (also referred to as agenda setting) and the final step of the cycle is policy evaluation. The steps in between vary slightly across literature, mainly in formulation and level of detail, see Table 3.1 (Howlett & Ramesh, 2003; Fischer & Miller, 2006; Howard, 2005). Figure 3.1 shows the different stages of the policy cycle that is used for this research and the activities that occur within each stage.

Table 3.1: Overview of policy cycle stages

Howlett and Ramesh (2003)	**Fischer and Miller (2006)**	**Howard (2005)**
Agenda setting	Agenda setting	Agenda setting Analysis of the policy issue
Policy formulation Public policy decision-making	Policy formulation and decision-making	Formulation of policy responses Decision to adopt a specific policy response
Policy implementation	Implementation	Implementation
Policy evaluation	Evaluation and Termination	Evaluation

In the next sections, the phases of the policy cycle are discussed in more detail and consecutively, the role of the Y-factor within these stages is excogitated. The Y-factor was developed to address the issue of lowering carbon emissions and because this is established as a prerequisite, the stage of issue identification/agenda setting is not further discussed. This stage is consequently given a grey colour in Figure 3.1.

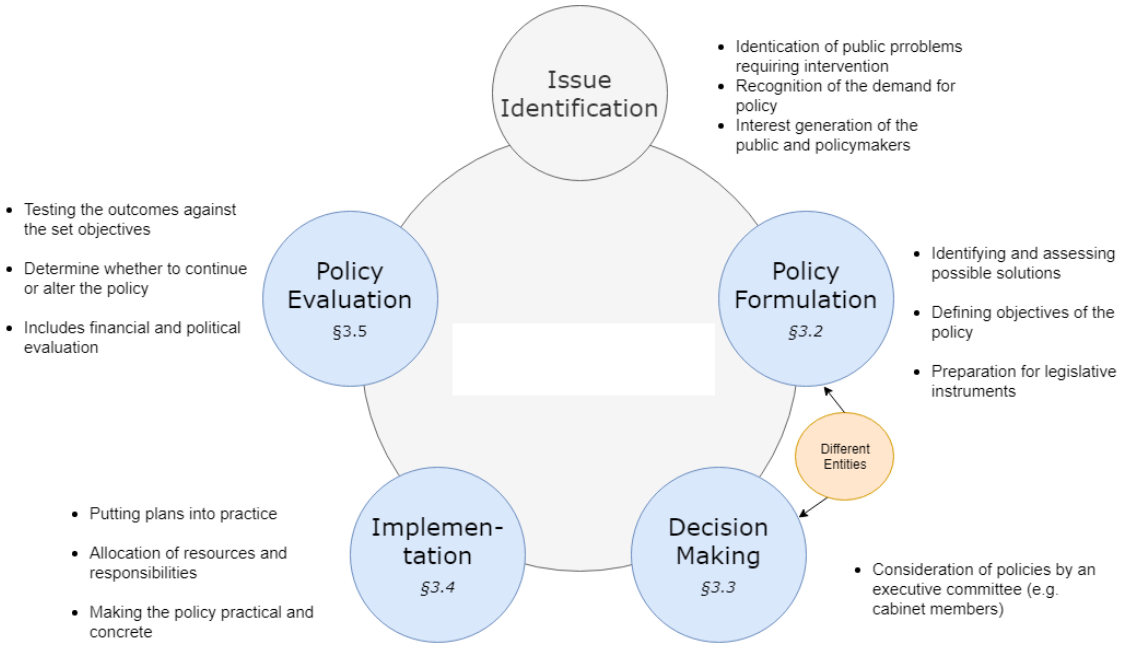

Figure 3.1: Phases of the Policy Cycle

3.2 Policy formulation

The policy formulation stage follows the issue identification stage in the policy cycle. Within this stage, objectives are specified and policy options are formulated to solve the identified problem and meet the objectives (Wolman, 1981). As Hill and Varone (1997) address it, issue identification is about where to go and policy formulation is about how to go there. Consequently, it shapes the subsequent stage of decision-making (Linder & Peters, 1990). Fischer and Miller (2006) address policy formulation as the pre-decision phase of policymaking.

Within the stage of policy formulation, policy analysts are presented with the task to address the public demands that were raised in the stage of issue identification and confront these demands as trade-offs with political, technical and financial capabilities (Turnpenny, Jordan, Benson & Rayner, 2015). This is done through the formulation and specification of different alternatives. It involves drafting a regulatory language for each alternative and describes the instruments needed to implement the policy (Turnpenny et al., 2015). Policy formulation can be executed by different types of actors like think tanks, ministerial employees or knowledge institutes. The ultimate goal of this stage is to develop a limited amount of policy options to present to the final decision-makers. Paragraph 3.2.1 clarifies the different tasks within the policy formulation stage, which is followed by an enumeration of the tools that have proven its ability to aid policy formulation (3.2.2). Paragraph 3.2.3 links the current capabilities and future possible applications of the Y-factor to the policy formulation stage by comparing it with the aforementioned tools.

3.2.1 Different tasks of the policy formulation stage

Policy formulation can be broken down into several tasks (Wolman, 1981). These are the following:

1. *Characterisation of the problem as an extension of the agenda-setting*: the public problems raised in the issue identification phase are not always self-evident and often prone to subjectivity. This task characterises the problem based on selecting evidence to support action on specific issues.
2. *Problem evaluations*: The policy-relevant dimensions of the problem are evaluated to determine their causes and extent, to serve as a basis for the identification of policy solutions. The understanding of the causation helps to design policy that can effectively deal with the problem.
3. *Specification of objectives*: After a consensus on the nature of the problem, responses and objectives are defined. These objectives can be reflected upon in a later evaluation stage.
4. *Assessment of policy options and recommendations on policy designs*: this component involves comparative assessment of the different policy options to guide the decision-making in a later stage. This component of the policy formulation is a less extensive form of multi-criteria assessment, compared to the one that is described in the next section on decision-making.
5. *Design of the policy - determining the preferred policy mix*: This involves the development of policy specifics (e.g. what regulations, market-based instruments or informational measures are required). Policymakers select from these instruments to establish a preferred policy mix.

To facilitate these tasks, many different tools were developed over the last decades. A selection of these tools is presented in the next paragraph.

3.2.2 Tools within the policy formulation stage

The first tool to facilitate the formulation of policies was constructed in the 1970s. In this period of time, most policy formulation tools focused on rational analytics. Simplistically said, problems were identified and solved using analytic tools. These tools, however, could not very well address political, behavioural and social aspects as these were filtered away by the rational approach. This led to criticism stating the tools were (too) econocratic (Radin, 2013), which, in turn, caused a complete turn-away from policy formulation tools in the 80s and 90s.

Currently, the use of tools for policy formulation has been rediscovered, because of several reasons. Turnpenny et al. (2015) state that these tools are increasingly used, because 1) it allows for rationalising the public perception on problems, 2) new technologies allow for more sophisticated use of tools, such as computer-based modelling, 3) a more networked society asks for more carefully picked policies and policies that can be rationally argued for.

Dunn et al. (2012) distinguish three categories of tools within the policy formulation stage. This categorisation is used to see if and where the Y-factor could fit in this stage, based on its characteristics. Also, possible additions that are necessary to fit in are then specified. The three different types of tools are the following:

Forecasting through the use of scenarios: This is primarily used in situations with high (scientific) uncertainties.

- The Y-factor does not yet have an option to establish scenarios or make future forecasts.
- The Y-factor does contain two barriers that could raise the need for a scenario analysis: information on technological uncertainty (C3) and unclear responsibilities of actors (B3). High scores on these barriers could raise the necessity for a scenario analysis, but it is very unlikely and illogical to further develop the Y-factor into a tool that could facilitate future forecasting.

Identifying and recommending policy options: this is done by conducting different analyses, such as cost-benefit analysis, cost-effectiveness analysis or a multi-criteria analysis)

- This could be one of the core components of the Y-factor. The Y-factor has the potential to identify policy options based on multiple criteria. This application fits within the earlier addressed stage on 'assessment of options based on a comparison of potential impacts'.
- For the Y-factor to be more suitable within this stage, several functionalities could be added. These are addressed in paragraph 3.2.3.
- The objective of this stage shows many similarities with the decision-making stage, which is based on multi-criteria decision analyses. This is further specified in section 3.3.

Problem structuring or framing: tools, such as brainstorming, boundary analysis and argumentation mapping can be used for this. These tools can provide a solid background for argumentation.

- The Y-factor is not yet adapted for facilitating discussions
- Slight alterations could be used to allow the Y-factor to structure discussion between policymakers with conflicting opinions. This is further specified in paragraph 3.2.3.

3.2.3 Linking policy formulation tools to the Y-factor

Within the phase of policy formulation, the Y-factor can be applied in multiple ways.. The list below presents the applications that the Y-factor already inhibits and is followed by a list of aspects on which the Y-factor could improve to become more suitable in the policy formulation stage.

The Y-factor is suitable when:

- Policymakers want to introduce a specific carbon abatement measure but are uncertain what barriers to implementation are present. The Y-factor can provide this information.
- There is a wish to reduce carbon emissions, but it is unclear which abatement measure is most effective or is the easiest to implement.
- Within a group of policymakers there is a disagreement on whether to implement a certain abatement measure, or whether it is easy to implement this measure. The Y-factor could be used as a form of argumentation mapping to structure discussions related to this disagreement.

There are certain components of the policy formulation phase, which cannot be incorporated in the Y-factor:

- Future forecasting (scenario analysis): As mentioned in the previous paragraph, it is not realistic to use the Y-factor for forecasting.
- Currently, policy design (step 5 in paragraph 3.2.1) is not yet incorporated in the Y-factor. What policy measures (specific instruments) would be effective to meet policy objectives? This could be a functionality that adds value to the Y-factor and also fits in well within its current objectives.
- The Y-factor is a tool that uses multi-criteria analyses. To better compare abatement options, the Y-factor would benefit from several improvements on functionalities and layout.

3.3 Decision-making

The phase of policy decision-making follows the formulation phase. Possible policies are drafted during formulation, and executive policymakers make a final decision on which policy to implement during the stage of decision-making. Mwije (2013) refers to decision-making as "the process by which governments adopt a particular course of action or non-action choosing from among a relatively small number of policy options to resolve public problems". Crucial elements within this stage are the selection of a proposal, developing political support and enacting it into law (Dye, 1992). To come to a policy solution, decision-makers will choose based on the application of a set of criteria to alternatives (Fischer & Miller, 2006).
The decision-making stage shows similarities with the stage of policy formulation. In both stages, policies are assessed on a set of criteria, but small distinctions are present. Within policy formulation, policies are developed based on these criteria, whereas decision-makers pick a final policy (mix) based on the same or different criteria. As visualised in figure 3.1, one of the key differences and a primary reason why it is separated in this document, is because the actors in the two stages are often different. In practice, however, it can sometimes still be challenging to make a clear-cut separation between both stages, which is also why some scholars regard policy formulation and decision-making as sub-stages of the same stage in the policy cycle (see table 3.1).

The decision-making on policy options involves many different factors and criteria and is therefore often facilitated by the use of decision support tools. Paragraph 3.3.1 provides an overview of the different type of decision support tools. This is followed in paragraph 3.3.2 by linking the tools to the possible application of the Y-factor in the decision-making stage.

3.3.1 Tools within the policy decision-making stage

Puig and Aparcana (2016) state that there are three main types of tools that can be used in decision-making with respect to climate change adaptation:

- *Life-Cycle Analysis*: This is a technique to determine the environmental, economic and social impacts of a product, from its manufacturing till its end-of-life.
- *Cost-Benefit Analysis*: This is a methodology used to quantify costs and benefits over time to determine if a project is worth implementing.
- *Multi-criteria decision analysis*: This is a methodology to assess alternatives against individual, often conflicting criteria, and combining the resulting scores into an overall score.

The Y-factor makes use of multiple criteria to generate new insights, but hardly contains aspects of a Life-Cycle Analysis or the necessary detail of a Cost-Benefit analysis. Therefore, the Y-factor is for now primarily seen a tool that uses multi-criteria decision analysis (MCDA). The other two tool categories are not further addressed. The next paragraph continues on the important components and possible applications of MCDA.

3.3.2 Linking MCDA applications to the Y-factor

Possible applications of MCDA methods are: choice, ranking, prioritization, resource allocation, ranking and conflict resolution (Abu-Taha & Daim, 2013; Wang, 2009; Cohen et al., 2018). The Y-factor is a method, which provides information about different carbon abatement options and the barriers that complicate their implementation. It considers four different categories as relevant to judge the difficulty of implementing a carbon abatement option. The Y-factor already inherits some of the key elements of a successful tool in decision-making, but also lacks some. The enumeration below establishes what the Y-factor could potentially achieve, but also on what it still needs to improve. The Y-factor has the potential to be used for:

1. Choice: the selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved
2. Ranking: ordering alternatives from most to least preferred
3. Prioritisation: similar to ranking, including the quantification of relative advantages of one option over another
4. Conflict resolution: the settling of disputes between parties with incompatible objectives

To improve upon these options, several additions to the Y-factor need to be made. First and foremost, the possibility must be added to attach weights to certain criteria as for policymakers, some factors might be more important than others. Secondly, the Y-factor does not allow for measuring the impact that is effectuated when implementing an option. Soana (2018) highlighted the possibility of combining the Y-factor with the McKinsey MACC to show the marginal abatement costs per ton CO_2 and the abatement potential. A third possible addition to the Y-factor is the representation of possible co-benefits when implementing a carbon abatement option. Cohen et al. (2018) mention this as a valuable component of MCDA tools. This feature was also recommended during expert interviews concerning the possible applications of the Y-factor (Soana, 2018).
With regards to conflict resolution, the Y-factor might have the potential to play a role in structuring discussions and highlighting why objectives of different policymakers do not align. How to do this, is further addressed in chapter 4. The Y-factor is not suitable for making decisions regarding resource allocation, as this requires more specific information than the Y-factor can currently provide. Resource allocation requires information on the policy instruments that will be implemented, which the Y-factor can only steer towards, but cannot help to formulate specifically.

3.4 Implementation

The implementation stage of the policy cycle follows after decision-making and before the evaluation stage. It is the translation of a plan into practice (Mwije, 2013). The main characteristic of this stage is that it concretizes and further specifies the plans that were made in preceding stages. It, therefore, has a higher level of detail than its prior stages. The implementation stage has three core elements (Fischer & Miller, 2006):

1. *Specification of program details*: Implementation of policy demands for a clear action plan. It must be clear how the laws and regulations must be interpreted and which agencies are responsible for executing the program
2. *Allocation of resources*: The distribution of budgets, personnel and responsibilities.
3. *Decisions*: This implies the necessity of a structure on how decisions shall be carried out for individual cases. Mwije (2013) metions that the effectiveness of the implementation depends on how well bureaucracies execute the orders.

The essence of policy implementation is about choosing the right policy instrument to fulfil the policy objectives (Howlett & Ramesh, 2003). What policy instrument is the most effective, depends on the complexity of the problem, the target groups, the budget, the human resources and the supporting regulations that are in place (Sabatier & Mazmanian, 1983).

Linking policy implementation to the Y-factor
The Y-factor consists of barriers that indicate the difficulty of implementing carbon abatement options. Within the implementation stage of the policy cycle, it can, therefore, alert policymakers on what elements to pay specific attention to.
However, regarding the nature of the implementation stage as described throughout this chapter, the Y-factor has a remarkably lower level of detail than the level of detail that the activities within the implementation stage demand. To be useful for policy implementation, the Y-factor should include more information on what policy instruments (regulatory, financial, informational or organisational) might help to overcome high implementation barriers. Another option would be to develop a crossover function with a tool that helps to divide roles and responsibilities in a project. The development of these functionalities would however not align logically with the current application of the Y-factor. The Y-factor could, however, be used as a reference method; when a certain policy instrument is proposed for implementation, the Y-factor can be used to decide if the instrument aims at lowering the most relevant barriers of implementation of a certain abatement technology.

3.5 Policy evaluation

The policy evaluation stage follows the stage of policy implementation and depending on the outcomes of the evaluation, the cycle starts again with the policy formulation stage. The evaluation of policy does not necessarily take place at the end of the policy cycle. Fischer and Miller (2006) mention that policy evaluation could take on three forms, which are ex-ante evaluation, monitoring and ex-post evaluation. Ex-ante evaluation is done prior to the implementation of the policy and pre-assesses and anticipates on possible outcomes of the policy. Monitoring or 'ongoing evaluation' helps to identify interim effects of policy measures when implementation is still underway. Ex-post evaluation is the most common form of evaluation, which is also the evaluation that is referred to within the policy cycle. Unless explicitly mentioned otherwise, evaluation means ex-post evaluation within this document. This subsection establishes the goals of policy evaluation, the activities conducted during policy evaluation, the possible outcomes of policy evaluation and finally, how policy evaluation is linked to the Y-factor.

Objectives of policy evaluation
The aim of policy evaluation is to find out whether and to what extent a policy has accomplished its goals or whether it has had other intended or unintended effects (Anderson, 1975). Furthermore, underlying reasons and causalities that contributed to these outcomes are investigated to find out which parts of the policy need to be adjusted for higher effectiveness of the policy. A final reason for evaluation that is the public responsibility to be accountable towards civilians.

Activities of policy evaluation
Evaluation aims to discover whether the policy reached its objectives, what the underlying causes are and whether there are any relevant spillovers. Methods that are used for decision-making of the policy are also relevant for evaluation. Often used methods are multi-criteria analyses and cost-outcome analyses, such as cost-benefit, cost minimisation and cost-impact analyses. These methods can help to establish the impact of the intended policy. Furthermore, the used methods depend on the nature of the policy. Some policies can be very well quantitatively evaluated, whereas other policies have a more qualitative nature (Anderson, 1975).

Outcomes of policy evaluation
On a generalized level, the possible outcomes of the policy evaluation stage are fourfold (Anderson, 1975):

1. The policy is successful and is continued
2. The policy does not fully return its intentions and is modified to be more successful
3. The policy is strengthened: more focus and/or finances are liberated for this policy
4. The policy is terminated: various underlying causes could be defined, such as a lack of impact, lack of finances or the objectives are achieved and continuation is not necessary

Linking policy evaluation to the Y-factor
As mentioned in earlier sections of this chapter, the Y-factor can prove its value by providing a multi-factor approach to the development of policy on carbon abatement related topics. These factors can assist in the evaluation of policy in a similar way. The Y-factor can be especially helpful in determining the causes of either a successful or failing policy. If a policy has not achieved its objectives, this could be related to a wrongly specified focus of the deployment of instruments. Subsidies on a certain abatement technology might not prove effective if the key barrier to implementation is the absence of a structured division of responsibilities within the coalition of actors.
A second application of the Y-factor could be to provide a general framework for evaluation. Multi-criteria analyses are often used in policy evaluation to determine where the policy made an impact. An impact, which could either be intended or unintended. The application of this framework could help to determine the outcome of the policy evaluation. Modification of the policy could be done to lay more focus on tackling a certain barrier, or a policy could be terminated if the instruments' focus are completely wrong-directed.

3.6 Conclusion

Within this report, the policy cycle is used as a framework to foresee the possible applications of the Y-factor for policymakers. Specifically, the analysis in this chapter helps to determine functionalities that a Y-factor tool

(Chapter 4) should have. These functionalities, together with limitations are presented in Table 3.2 per phase of the policy cycle. Figure 3.2 graphically shows how the Y-factor can be used in the policy cycle phases.
The conclusion to the sub-question *"In what stages of the policy cycle can the Y-factor be applied?"* is presented in the next paragraphs.

3.6.1 Using the Y-factor for formulation and decision-making

Where to apply the Y-factor in the policy cycle also determines certain design choices for the Y-factor tool in Chapter 4. The primary focus of application for the Y-factor will be on the formulation of the policy and the consecutive decision-making. The main argument for this choice is that the requirements for these phases lie closest to the inherent nature of the Y-factor. The formulation phase and decision-making phase benefit from an analysis that helps to compare different policy options on multiple criteria. The Y-factor could support this process, due to its twelve criteria that spread across the most important categories that hamper the implementation of carbon abatement options. To facilitate the use of the Y-factor in these phases, there are still several aspects that require improvements. These are discussed in Chapter 4. Moreover, the Y-factor can be seen as complementary to other activities in the formulation and decision-making process and cannot account for all of them. The Y-factor is less adaptable for the implementation of policies at this stage requires a higher level of detail than the Y-factor can provide. The implementation stage translates the high-level direction from the decision-making stage into concrete policy instruments and resource allocation. The aim of the Y-factor does not comply with these activities. Even though it might prove more useful than in the implementation stage, the Y-factor also has a weaker match with the evaluation stage, compared to the stage of policy formulation or decision-making. This is because the main strength of the Y-factor is to combine multiple criteria to come to a decision regarding the formulation of a policy, rather than to look back at what criteria should have been applied beforehand. However, by providing a general framework of categories, the Y-factor might still prove its effectiveness in this stage and us therefore not completely left out of scope. The design of the tool in chapter 4, however, primarily focuses on making sure that the Y-factor can be used in such a way that it is beneficial within the stages of policy formulation and decision making.

3.6.2 Limitations

The main deliverable of the policy formulation phase is the outline of a policy and corresponding instruments. The Y-factor can help to provide the general outline of a policy in terms of the abatement options it should focus on and the barriers to implementation that need to be overcome. However, the Y-factor will not help with defining the actual policy instruments. The outcome of an analysis using the Y-factor will, for example, not directly lead to deciding on a tax increase of 2%. Furthermore, the Y-factor can be seen

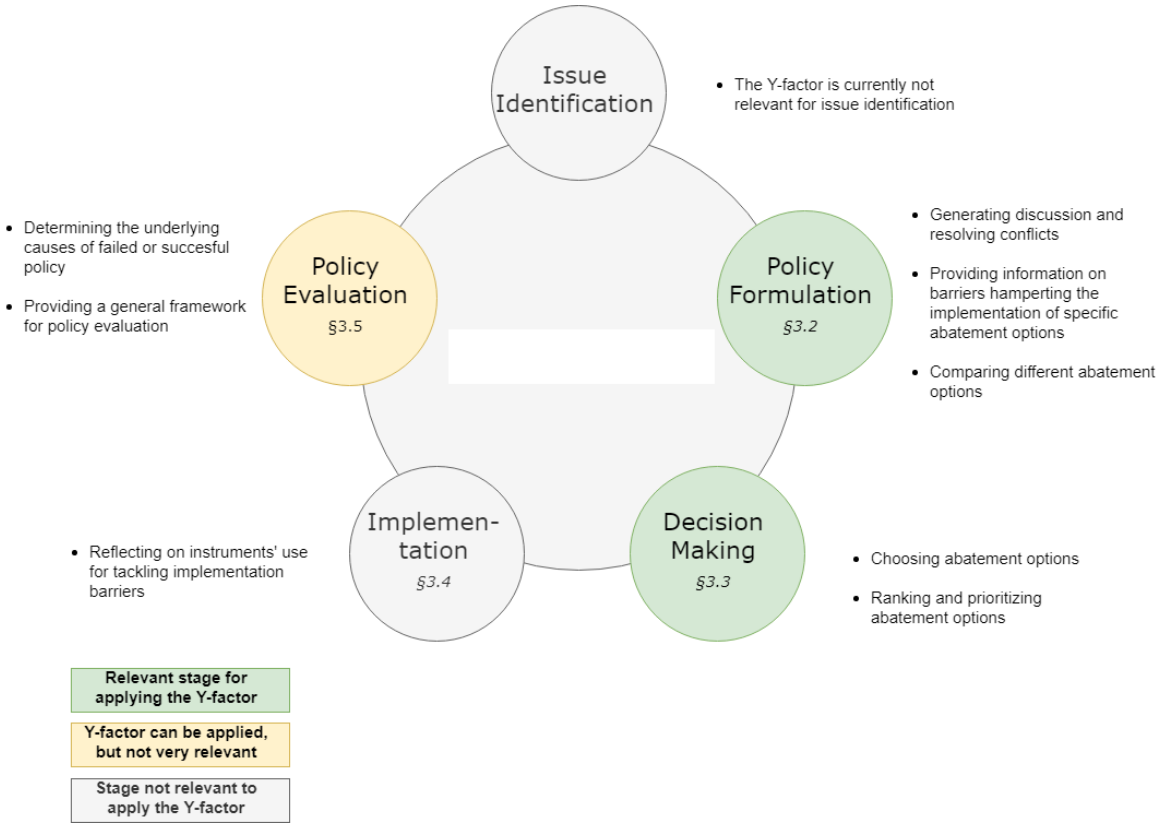

Figure 3.2: Applicability of the Y-factor in the Policy Cycle

as complementary to other decision making tools. The MACC developed by McKinsey might not incorporate all aspects that define on what technology to invest, but a merit of this tool is that it quantifies the impact of a technology, whereas the Y-factor attaches scores on a scale of 0 to 2. It might, therefore, be interesting to combine these tools.

Table 3.2: Y-factor applications per cycle phase

Policy Cycle Stage	Application Y-factor	Current limitations
Formulation	Generating discussion	Not suitable for scenario analysis
	Providing information on a specific abatement option	Design of specific policy instruments
	Comparing different abatement options	
Decision-making	Choosing an abatement option	Showing impact and co-benefits of abatement options
	Ranking and prioritizing across options	Adding own priorities and beliefs across Y-factor categories
Implementation	Reflecting on instruments' use for tackling barriers	Designing specific policy instruments
Evaluation	Determining underlying causes of failed or successful policy	Y-factor is too generic to serve objectives of policy evaluation
	Providing a general framework for policy evaluation	

4 Y-factor Tool

This chapter of the report is dedicated to the setup of the web-based tool that facilitates the use of the Y-factor and is investigated by answering the following research question:

How can the Y-factor be made more accessible and facilitated in use for policymakers?

This chapter first addresses and specifies the objectives of the tool in section 4.1, which are translated into concrete criteria in section 4.2. Section 4.3 describes the design choices made to adhere to the criteria. Section 4.4 shows the end result of the tool.

4.1 Y-factor limitations and objectives

The most recent deliverable of previous Y-factor research is a validated reference curve, highlighting twenty-four different carbon abatement options ranked on the twelve criteria that constitute the Y-factor. This curve is based on extensive research and a great deal of information ((Chappin, 2016; Cheung, 2018; Arensman, 2018; Soana, 2018), but still shows certain drawbacks, which hamper the wider use of the tool by policymakers.

4.1.1 Limitations of Y-factor reference curve

Throughout literature, the validity of the McKinsey MACC is a recurrent issue of debate. However, it still is a widely used tool for conducting research, and for the development of business strategies and public policy. For the Y-factor to be used as a successful complementary approach to the MACC, certain improvements are desired. A first drawback of the Y-factor as a reference curve is that it does not allow for contextual differences. During interviews of earlier Y-factor research (Cheung, 2018; Arensman, 2018; Soana, 2018), it was addressed multiple times that it was hard to attach scores to implementation barriers as these are very context dependent. Especially factors relating to multi-actor complexity can differ greatly in different (geographical) areas. Different complexities might arise in different countries, due to the presence of different actors having different interests and different values. The context dependency is more relevant for the Y-factor than for the MACC, as the marginal costs for initiating carbon abatement

options in different areas often differ less than multi-actor complexities and physical interdependences.

Apart from contextual differences, the scores attached to the Y-factor categories have a more subjective nature than the marginal costs that constitute the MACC. That out of the twenty different carbon abatement options that were validated by at least two experts, only two options were given the exact same score by the expert on each of the twelve Y-factor barriers (Soana, 2018), illustrates this subjectivity. The reference curve that was created is valid, but does not tell everyone's truth. To allow for these different opinions, the current curve does not yet provide any possibilities.

Being supported by four different pieces of research (Chappin, 2016; Arensman, 2018; Cheung, 2018; Soana, 2018), the Y-factor contains a lot of underlying information, which is relevant for understanding how to interpret the Y-curve. However, navigating through this information is currently not facilitated, which makes the Y-curve more complicated to understand. Moreover, as a reference curve, the Y-factor does not provide the option to only show the information that is relevant for its users. A policymaker that is responsible for drafting energy policies is less interested in abatement options regarding agricultural solutions. Currently, it is not possible to filter this information.

The next section addresses the objectives that the Y-factor tool should adhere to. A summary of the limitations and objectives is represented in Table 4.1

4.1.2 Y-factor tool objectives

Soana (2018) investigated how the Y-factor can act as problem-defining heuristic by highlighting the technical, institutional and behavioural problems that need to be resolved and consequently helps to reveal features of debated choices. This aforementioned analysis on defining the Y-factor as a heuristic, emphasises how the Y-factor functions as a framework to gain a broad-levelled insight into the complexity linked to the implementation of carbon abatement options, rather than being a tool for detailing how to implement new carbon abatement policies.

The general objective of the tool is to support the policymaking process as described in chapter 3, by incorporating outcomes from earlier Y-factor research and adding functionalities to generate more insights from these outcomes. An important and recurrent element from earlier research is the wish for flexible employability of the Y-factor. As mentioned in the previous section, the Y-factor contains a lot of information on multiple carbon abatement options. However, different policymakers often show interest in different information. Therefore, the tool should allow for an easy way to exclude information that is not deemed relevant by its user. This would mean that if a policymaker wants to compare the implementation complexity of a solar park with a wind park at sea, only these scores would be shown and all other information is hidden.

A second element of flexibility that could improve the Y-factor tool, is the possibility for policymakers to change the values of the Y-factor according to differences in their beliefs or (geographical) context. Not only different scores could be given, but also different importance could be attached to certain elements. If a policymaker has a very strong influence on the actors involved with a new project, the complexity concerning multiple actors might be less of an issue, but if there are not a lot of finances available, more attention would be drawn towards finding available options with lower associated costs. Policymakers should, therefore, be able to change certain values in case the situation they are confronted with differs from the assumed situation that led to the creation of the reference curve. Not only does

A third aspect that the Y-factor could improve upon is to show the impact of implementing abatement options. The McKinsey MACC quantifies the impact of implementing technologies by showing their global carbon abatement potential in 2030 and the marginal costs that are associated with this implementation. This makes the McKinsey curve more tangible than the Y-factor. Soana (2018) suggested combining both curves into one scatter plot, which can be seen in figure 4.1. For the tool, it is beneficial if the financial impact and abatement potential could be included in a similar fashion. A final element, which was mentioned in the research by Arensman (2018) and is also concluded from Chapter 3 is the merit of showing co-benefits of abatement options.

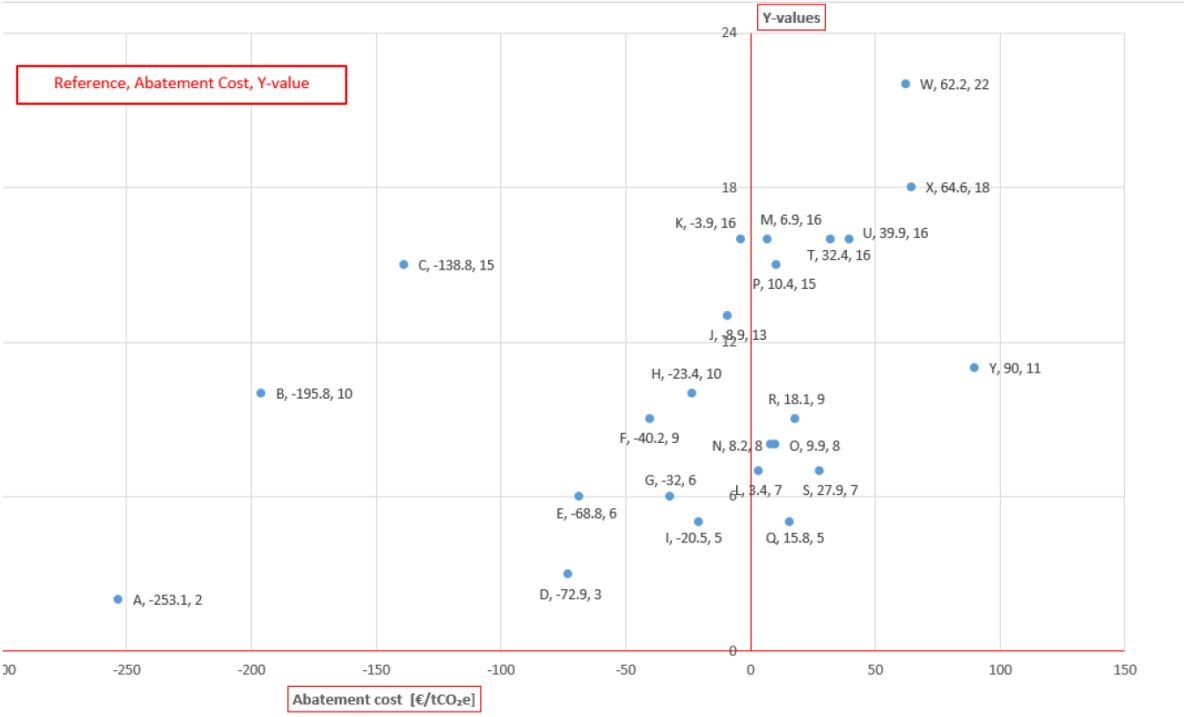

Figure 4.1: Scatterplot combining Y-factor and McKinsey Curve (Soana, 2018)

The first paragraph of this section mentions that the Y-factor shares insights into the complexity of implementation, rather than detailing the policy instruments that must be introduced. However, these insights into the

complexity should eventually lead to further narrowing the scope of the to be implemented policy. As the tool aims to facilitate the formulation of new policies, an important objective of the Y-factor tool is therefore to generate and structure discussions on what policy could be implemented. The Y-factor contains several elements that allow for discussion between policymakers. Especially with the added possibility of attaching weights and new values to the Y-factor, the interaction between policymakers can be stimulated by discussing why certain weights differ across policymakers and why there might be a difference of opinion. Moreover, the tool should generate new insights for policymakers on the relative complexity of abatement options. The aim of the tool is to provide a unique set of factors that portrays a full comprehensive understanding of the relevant issues that need to be taken into account when considering climate policy, and to understand what the effect is on the suitability of abatement options when certain complexities are either heavier or lighter in a particular situation.

Many of the aforementioned objectives overlap with the conclusions that are drawn in Chapter 3. One aspect that is shown in Table 3.2, which has not yet been incorporated in this enumeration of objectives is the need for detailed information on specific carbon abatement options. This is needed for the policy formulation and can also be beneficial for the other stages of the policy cycle. Evaluation of a failed policy could, for example, be done better if there is sufficient information available that provides insight into how Y-scores are calculated. Table 4.1 summarises the list of objectives that are mentioned. Section 4.2 concretises these objectives into a list of functional and non-functional criteria.

Table 4.1: Y-factor limitations and objectives

Limitations Y-factor reference curve	
Static	Does not allow for contextual differences Does not allow for user input and preferences
Hard to find information	Does not allow for easy navigation through information Does not allow for filtering information
Objectives Y-factor tool	
Flexibility	Give user freedom to decide what carbon abatement options to include Let users attach weights to Y-factor barriers Let users change Y-values based on beliefs or context
Impact	Show CO_2 abatement potential of carbon abatement options Show marginal abatement costs of carbon abatement options Show co-benefits of carbon abatement options
Specific	Providing all the necessary information on the Y-curve and the different abatement options Allowing for clear comparison between different carbon abatement options
Interaction	Generating discussions between policymakers Generating new insights for policymakers

4.2 Tool criteria

The tool is created with the objective to facilitate policymakers with their activities that range from formulating policies, deciding on which policy to choose and evaluating policies. It is created for visualising the Y-factor and making it easier to use and understand. To test the objectives that were specified in section 4.1, a list of criteria is presented below. These criteria are formulated to assess to what extent the Y-factor tool meets it objectives, but also to assess the usability (ease of use) of the support tool. During interviews in previous Y-factor research Arensman (2018), Soana (2018), the lacking ease of use compared to the McKinsey curve was mentioned recurrently and are, therefore, taken into serious consideration with the design of the Y-factor tool.

4.2.1 Usability and flexibility criteria

Ease of use or usability is seen as an important factor in software adoption and can be characterised by 5 criteria (5E's): effectiveness, efficiency, engagement, easy to learn and error tolerant (Quesenbery, 2003). As every tool is different, these 5 dimensions are not equally important in all tools. The importance of each of the dimensions is represented in Table 4.2.

Effectiveness: This criterion is about whether the user can do what it wants to do with the tool. The Y-factor tool will be introduced to users as having certain features. The score on effectiveness will be higher if the user of the tool manages to fulfill the task that he or she intended to fulfil.

Efficiency: Is about the speed and accuracy with which the tool can fulfil its goals. If the users easily understand how to navigate through the tool and understand what components intend to do, it can be applied quickly and efficiently.

Engagement: This criterion assesses how pleasant, satisfying or interesting an interface is to use. It determines whether the tool easily draws someone into using it.

Easy to learn: Determines how well the product supports initial orientation and deeper learning. Does the tool require a lot of time to control and understand, or can it be learned quickly? And is there a fast learning curve, making it easier to use the tool for a second time?

Error tolerant: This criterion determines how well the tool can prevent errors, but also whether errors can be easily solved when it occurs. An example would be that a user hits the wrong button, and hereafter does not know how to return to the main page of the tool.

Table 4.2: Criteria for usability assessment

1	Effective
2	Easy to learn
3	Efficient
4	Engaging
5	Error tolerant

For the Y-factor, not all usability criteria are equally important. First of all, the tool has specific target users. This makes it less relevant to have a very engaging interface, whereas it becomes increasingly important to have an effective tool. If the tool does not present the functionalities that the user wants to have, it loses its relevance. As the tool development originates from a wish to facilitate the adoption of the Y-factor, the easy to learn criterion also weighs strongly. The same is true for the efficiency of the tool as it is meant to facilitate users and providing quick, accurate and therewith efficient results has added value. Being efficient and easy to learn, also requires a basic and clear-cut interface. This inherently lowers the chance of errors and having this as a criterion is therefore deemed less relevant. Table 4.2 shows the relative importance of the 5Es for the Y-factor, with effectiveness being most important and error tolerance least.

Regarding the criteria for the tool, one final criterion is added, which is **flexibility**. As mentioned in section 4.1, the tool is designed to have multiple different applications. This criterion determines whether the tool can be tailored by the user itself towards his/her intended purpose. Can the user easily find and apply the functions of the tool that are most relevant for his/her purpose?

A well-known concept when it comes to any sort of design is the *Flexibility - Usability trade-off*. This concept describes how flexible designs can perform more different functions than a specific design, but also makes it less effective and efficient. Finding a balance between developing a usable and flexible tool is, therefore, a design challenge which is also very relevant for the development of the Y-factor tool. The aim of the tool is to allow policymakers to use the Y-factor in a way that specifically suits him/her best, and therefore be flexible in use. However, if this means that this would lead to a lower score on one of the five usability criteria as shown in figure **??**, the amount of flexibility needs to be reconsidered. Figure 4.2 shows an abstract representation of the trade-off, where the Swiss army knife represents a flexible design, and the kitchen knife the more usable design.

The Y-factor tool has a clear objective for its design, which is to facilitate the use of the Y-factor for policymakers. This implies that the Y-factor shall be given more functionalities (as described in section 4.4), which makes the Y-factor more flexible in use. However, the tool adheres best to its objectives when the Y-factor becomes more comprehensive, more effective and easier to use. This means that the design should focus more on being 'usable', rather than being 'flexible'.

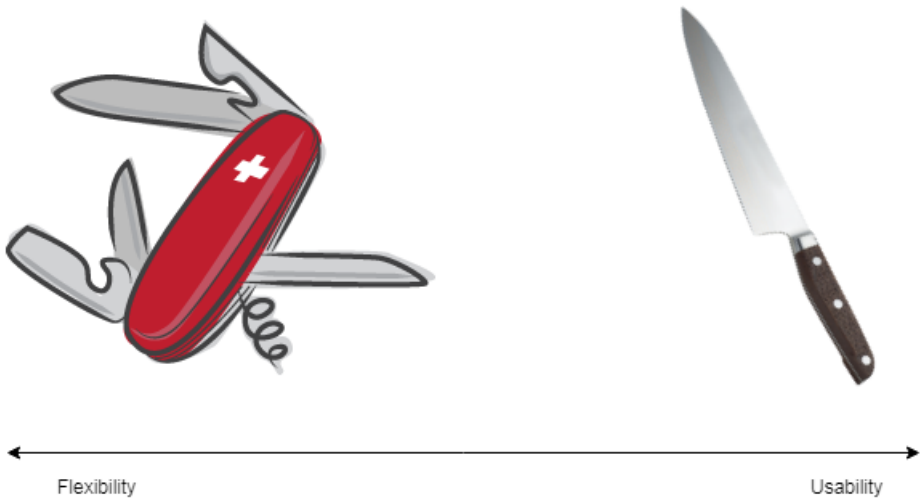

Figure 4.2: Flexibility - Usability Tradeoff (SmashIcon,2019)

Table 4.3: Criteria for usability assessment

Usability criteria	
U1	Effectiveness
U2	Efficiency
U3	Engagement
U4	Easy to learn
U5	Error tolerant
Flexibility criteria	
F1	Flexibility

4.2.2 Assessment of the criteria

This paragraph describes how the tool is assessed on the different usability and flexibility criteria. Partly, this is done by observing user experiences during the focus groups (this is discussed in Chapter 5), and partly by conducting a survey amongst the focus group participants. Within this survey, questions are asked that provide information on the usability and flexibility of the Y-factor tool. A well-established measure to quantify the usability of a design is the System Usability Scale (SUS).

The SUS is a quick and dirty way to measure usability (the appropriateness to a purpose) of any particular artefact (Brooke, 1986). This usability is measured by providing users with 10 statements that need to be rated on a scale of 1 to 5 where 1 amounts to 'Strongly Disagree' and 5 amounts to 'Strongly Agree'. The list of usability questions is the following:

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system

5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

As this method was used in many situations concerning usability testing, multiple reference cases exist that determined whether designs were easy to use or not. The usability score can be calculated by (Brooke, 1986):

1. For each of the odd-numbered questions, subtracting 1 from the score.
2. For each of the even numbered questions, subtracting their value from 5.
3. Taking these new values, and sum the total score. Then multiply this by 2.5.

The SUS ranges from 0 to 100. An average score on the SUS is 68 and above 80.5 the design is valued as being excellent by its users (Brooke, 1986). The total questionnaire can be found in Appendix B.

4.3 Design choices

To make the tool easily accessible for its users, it is built to be web-based. The criteria that are established in the previous section demand for an easy-to-use tool, that provides sufficient information, and can be flexibly tweaked to the user's wishes. By visualising the Y-curve, a cross-over with the McKinsey MACC and providing the possibility to tweak data based on the user's own knowledge, the tool can adhere to the criteria as mentioned in Table 4.3. The web-based tool has an HTML basis and the visualisations were created using the Javascript D3 library. The main advantages of using the D3 library are the following:

- D3 can be used to make interactive visualisations
- D3 can visualise a simple dataset into many different visualisations
- D3 uses Javascript and can, therefore, be used in combination with other languages, such as CSS and HTML. Moreover, it can be opened with all (recent) web browsers
- D3 easily adapts its visualisations when the dataset is altered

The Y-factor tool is designed in a way that it supports any dataset as long as the names of the columns are identical to the specified names in the Javascript coding. Each row in the dataset represents a carbon abatement option and needs to specify: the name of the carbon abatement option, scores on

each of the twelve barriers, the marginal abatement costs in €/tCO2eq, the carbon abatement potential in MtCO2e in 2030, general information on the carbon abatement option, and information on the main barriers that could complicate implementation of the abatement option. The dataset is formatted in a tab separated values document (TSV). This file can easily be created and opened in Microsoft Excel. The reason for choosing a TSV file as a data source is to enable descriptions of abatement options to contain comma's or semicolons. These cannot be used in CSV files, which are more normally used as datasets. The rest of the chapter describes the choices regarding the layout and the functionalities of the Y-factor tool.

Lay-out

An appointment with Steven van der Kwartel, who is a graphic designer and web designer, was conducted to improve the design of the web-based tool (Van der Kwartel, April 25, 2019). His job as a graphic designer, in combination with his background in psychology, provides him with the expertise on how a web page can be visualized to steer user's focus on what is necessary and display the information in a clear manner. Van der Kwartel mentioned the importance of using a clear structure in the web design in terms of size and colour. Using clear structures, users will not be distracted towards layout-related aspects. Several examples are same font-size, same font-colour, alignment of columns and headers, centering of text, using the same margins. Furthermore, van der Kwartel highlighted how screen sizes will never be the same again and how websites should be designed responsively. As the Y-factor is intentionally designed to be easily accessible, the aspect of being responsive is very important. This would allow users on all screen sizes to be able to work with the Y-factor tool. On a content level, van der Kwartel mentioned how it was hard to read the data from the bar chart to see the Y-value per technology. He suggested to either use a table or a raster for the grid.

Many of his recommendations were implemented. However, some recommendations are too time intensive to be incorporated into the design within the scope of this research project. Chapter 7 provides an overview of these recommendations for further improvement.

4.4 Y-FACTOR TOOL

This section describes how the tool was developed with regards to design and functionalities. A manual on how to use the tool can be found in Appendix A. This chapter describes the different components of the tool and how they adhere to the criteria that are described in section 4.2. The different components of the Y-factor tool are displayed in figure 4.3

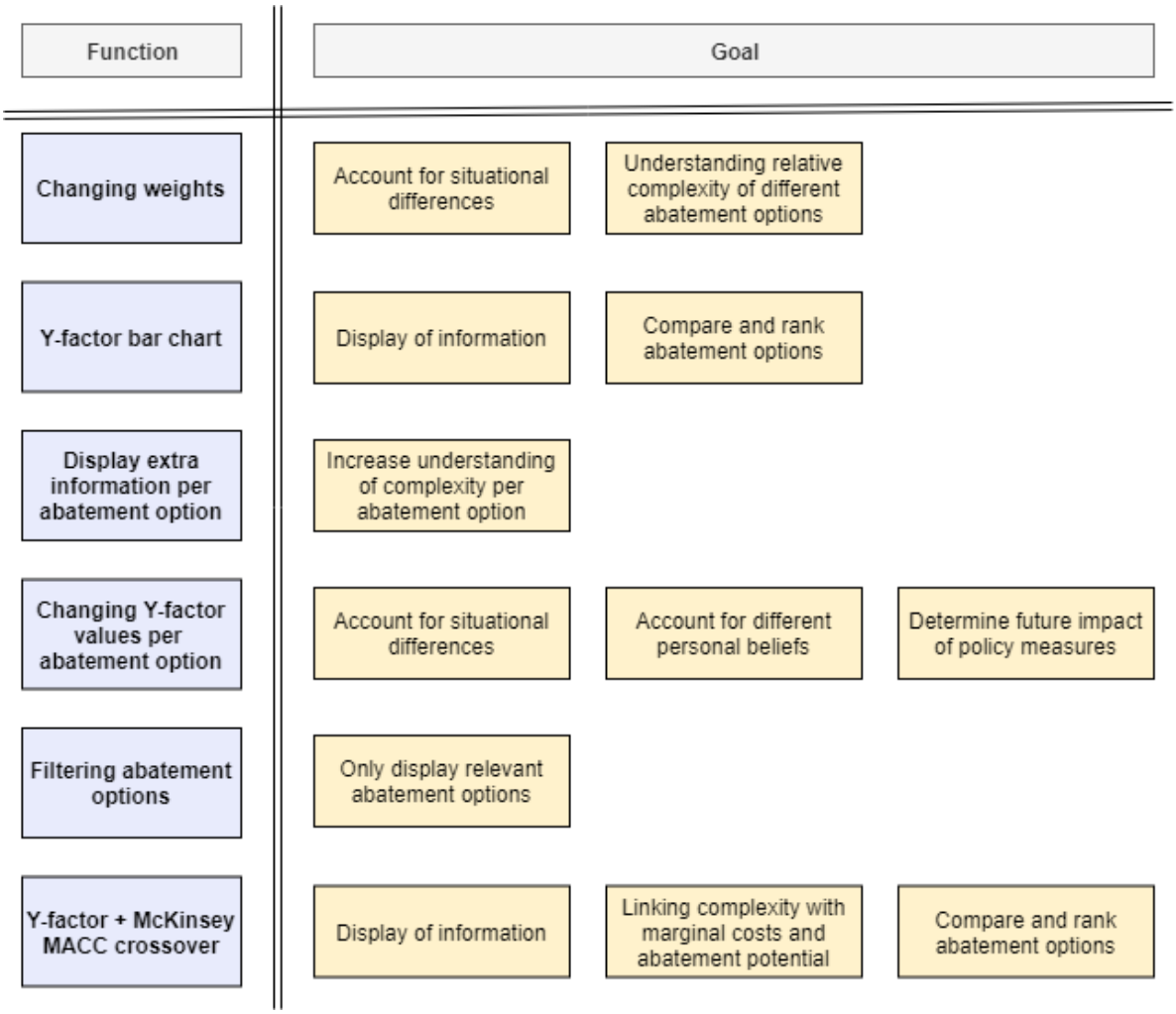

Figure 4.3: Y-factor tool functions

Y-factor bar chart

The Y-factor bar chart displays the scores that are linked to the barriers on which each carbon abatement option is ranked. The curve is automatically sorted from a low score (easiest to implement) on the left to a high score (hardest to implement) on the right. The curve can be displayed in two levels of detail: on a 4 category-level (Costs and Financials, Multi-actor Complexity, Physical Interdependences and Behaviour) or on a 12-factor-level, with each category subdivided into three Y-factor barriers. Changing this level of detail can be done by clicking the button 'Toggle level of detail' which can be seen in Figure 4.4.

Attaching weights to factor scores

To be suitable as a multi-criteria decision making tool, the possibility to attach weights to individual factors is included in the Y-factor tool. Below the Y-curve, a menu is attached with the possibility to attach weights. This can be seen in Figure 4.5. The size of the bars in the bar chart change

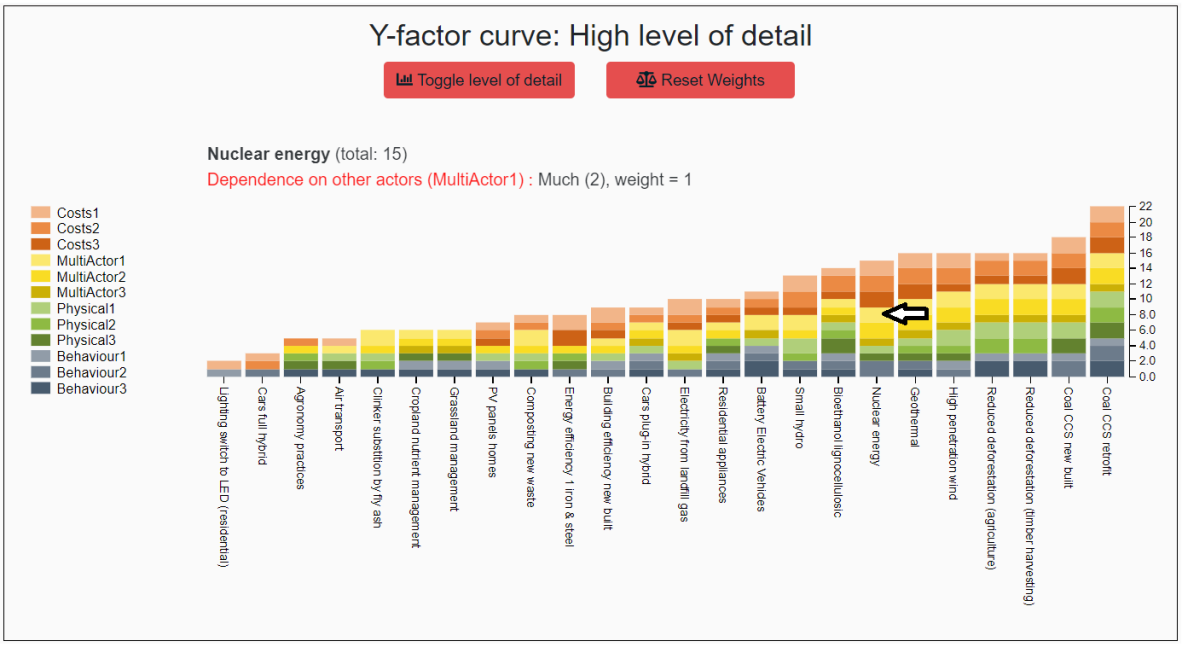

Figure 4.4: Y-curve 12-factor view

their size automatically when the weights sliders are adjusted. However, the scores on the Y-factor criteria are ordinal and attaching a weight only shows the relative importance of a factor, but does not change the ordinal value. Thus, it is important to interpret the results in a correct manner when attaching weights. When hovering the cursor over the bar chart, it, therefore, shows the original factor score and the weight that is attached to it.

Attaching weights to certain Y-factor barriers should tell something about the context in which the user (policymaker) operates. This is because weights are factor specific, but not specified per carbon abatement option. E.g. increasing the weight of the payback-time factor (Costs2) implies that in the policymakers' context, it is relatively harder to implement abatement options when there is no guaranteed return on investment within a short period of time. Apart from adjusting weights to allow for context-specificity, it can also be used more conceptually by giving policymakers a feel of what abatement options become more or less attractive when complexities change.

Changing Y-values per technology

A third function that the Y-curve tool inhibits is the possibility to attach new values to the Y-factor criteria. By clicking the abatement options in the menu on the right side of the tool, extra information on the specific abatement option appears together with the current values that the criteria were given in the reference curve. In this menu, these values can be altered and submitted, which causes the curve to change automatically. To make sure that the values are well-understood, every technology is provided with a description and an enumeration of the main barriers to implementation.

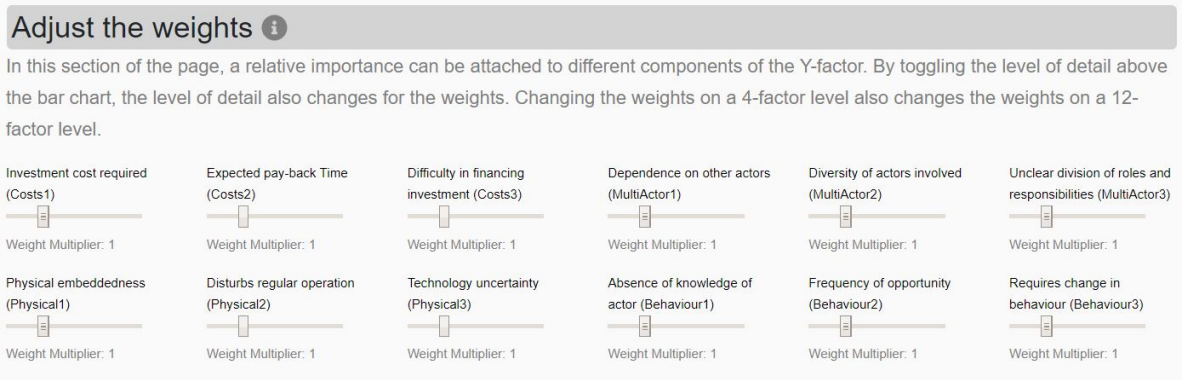

Figure 4.5: Adjust weights of Y-factor criteria

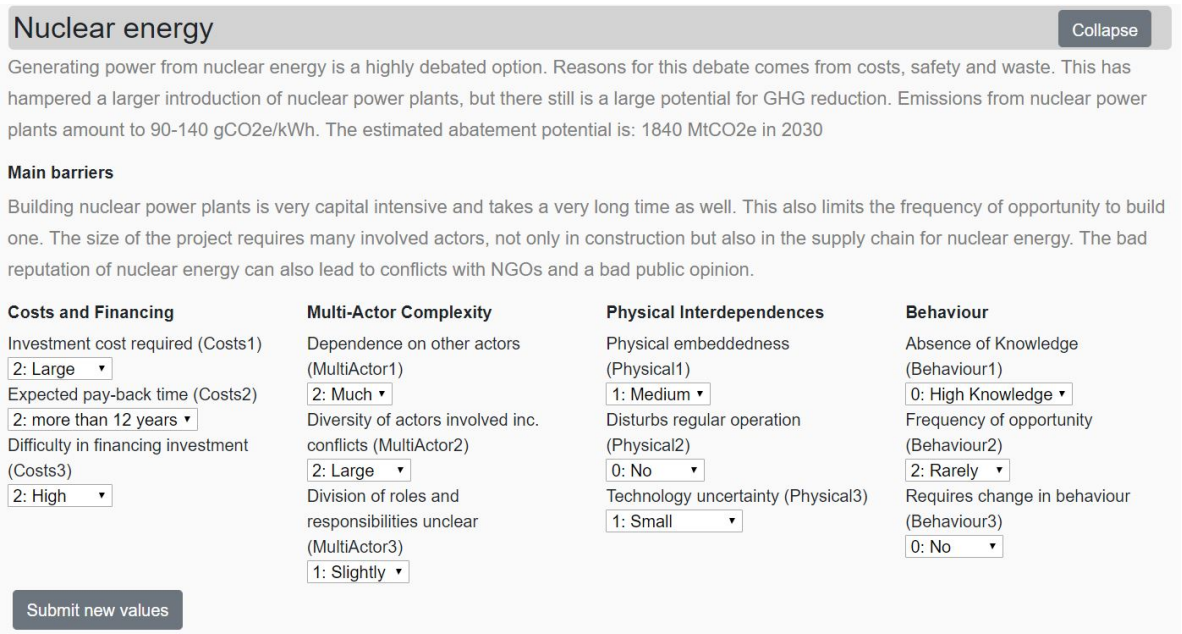

Figure 4.6: Change Y-factor criteria values

The function can be seen in Figure 4.6. These descriptions are summaries of the research done by Naucler and Enkvist (2009) and Soana (2018).

The option to change Y-factor values of carbon abatement options provides policymakers with the possibility to change the Y-curve if they do not agree with the reference values that were attached to the barriers. As the reference values are based on only two interviews and in many cases still are fairly insecure, it is not unimaginable that the policymakers' beliefs might differ slightly from the values that are currently in the Y-factor. Moreover, a different context might imply different complications for implementing certain carbon abatement options. E.g. privatisation and decentralisation of the energy market would mean that many more actors would be involved when constructing wind farms, which in its turn increases the multi-actor complexity. As regulations can vary strongly across countries, Y-factor values do too.

Figure 4.7: Filter abatement options

Filtering carbon abatement options

A fourth major function is the possibility to exclude certain carbon abatement options from the graph. This can be done when these options are not of interest to the policymaker. By clicking the checkboxes that belong to the abatement options, and submitting these, a selection is made to display in the curve. By clicking the carbon abatement options in this list, there is an information button that, when clicked on, displays the same information as shown in Figure 4.6. The list of abatement options to filter is shown in Figure 4.7

Crossover Y-factor and MACC

The second graph of the webpage tool displays the bubble chart that combines the Y-factor results with the McKinsey MACC. This is done in a similar fashion as done by Soana (2018), which can be seen in Figure 4.1. The filter that is shown in Figure 4.7 also works for displaying the information in this bubble chart. The numbers 1 to 24 are attached as labels to the dots in the bubble chart to make it easier understandable. Furthermore, a tooltip function is added to this graph as well, to display the values of each dot when the cursor moves over it. These functions can be seen in Figure 4.8.

What is added as an extra feature in this bubble chart, compared to Soanas' graphic, is the display of the abatement potential that can be achieved with implementing carbon abatement options. This is represented by the width of the dots. By adding this feature, the graph contains three valuable pieces of information per abatement option: the abatement potential in 2030 (in MtCO2eq), the marginal abatement costs (in €/tCO2eq) and the Y-value.

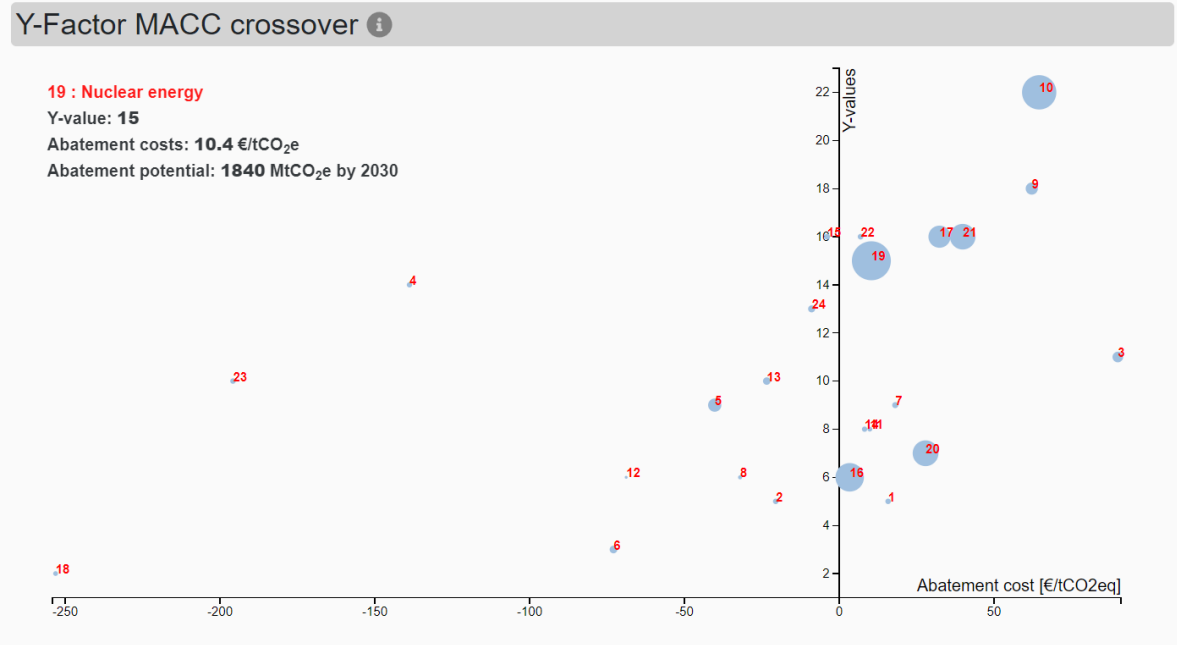

Figure 4.8: Crossover of Y-factor and MACC

Some minor aspects of the tool that are included to improve the usability are:

- Tooltips that appear when the cursor hovers over elements of the curve. When it passes over the bars, the abatement option, the selected factor and its associated score pop up in the top-left of the curve. See Figure 4.4. When it passes over the legend, more information is shown above it.
- The chart automatically sorts itself from left to right. This also happens when weights or values change. Therefore, the carbon abatement option that is easiest to implement will always be shown on the left side of the chart.

4.5 Conclusion

This chapter investigates the following research question:

"How can the Y-factor be made more accessible and facilitated in use for policymakers?"

The developed Y-factor tool gives policymakers the possibility to gain insights into implementation complexities, to adjust Y-factor values to their own beliefs or geographical contexts, to generate and structure discussions and finally to analyse abatement options on both the Y-factor and the McKinsey MACC. The tool is developed by identification of the limitations of the existing Y-factor reference curve: the Y-factor as a reference curve is static as it doesn't allow for contextual differences, user input or user preferences. Furthermore, the Y-factor contains underlying information that is relevant for understanding the reference curve, but this information is not easily accessible. Moreover, this information cannot be provided specifically to the users wish, as there is no easy way to filter information on specific technologies only.

By taking these limitations into account and by implementing recommendations from previous Y-factor analyses and the policy cycle analysis from chapter 3, a set of objectives was formulated to improve the Y-factor. These objectives state that the Y-factor has to become more flexible in use allowing for policymakers to change and filter information. Furthermore, the Y-factor was created as complementary to the MACC, so a way to show the Y-values in combination with MACC-values has to be found. Also, the underlying information supporting the Y-factor has to become more accessible and finally, the Y-factor would become more valuable if it stimulated interaction and discussions across its users.

To satisfy these objectives, a web-based tool is designed, which is built to adhere to criteria that determine the usability and flexibility of a system. This tool is designed using the D3.js Javascript library, hosted on an HTML web page. This allows for dynamic visualisations, but also provides easy access to anyone with an internet connection.

This Y-factor tool includes several new functionalities to improve the accessibility and ease of use of the Y-factor for policymakers. The created tool allows users to change relative factor weights, change Y-factor values per technology, see underlying information determining scores, filter abatement options, and access a scatterplot that shows how the Y-factor and the McKinsey MACC can complement each other.

5 Focus Group and Interview Design

5.1 Introduction

Chapter 4 described how a visualisation tool can facilitate the use of the Y-factor for policymakers. The aim of this chapter is to present a research methodology that can test how the Y-factor t tool is valued by policymakers and whether its application in the policy cycle as defined in Chapter 3 is validated. The sub question of this chapter is formulated as follows:

How can the applicability of the Y-factor tool in carbon abatement policymaking be tested in focus groups?

To investigate this question, this chapter is structured in two main sections. Section 5.2 explains the focus group methodology, highlighting crucial components of focus groups and establishing what type of organisations are preferable for conducting the focus groups. Section 5.3 describes the practical setup and the contents of the focus groups.

5.2 Why use focus groups?

Focus groups can be widely used and have a diverse scope of applications. It is used for market research, human factor research and usability evaluation (Bruseberg & Mcdonagh-Philp, 2002) The focus group methodology uses group discussion to solicit ideas and feedback about a product or a concept (D. Morgan, Krueger & King, 1998) and is often seen as similar to semi-structured group interviews as the techniques relate to uncovering people's perceptions and values (O.Nyumba, Wilson, Derrick & Mukherjee, 2018). However, an important distinction is that focus groups rely on interaction within the group, based on topics that are supplied by the researcher (D. L. Morgan & Krueger, 1997).

5.2.1 Advantages focus groups

There are a couple of motives to choose this research method. First, a focus group helps to generate discussion with real stakeholders in the policy arena. By bringing together participants with expertise and activity within the domain of policymaking on climate, new information can be obtained. When

moderated well, a structured discussion often generates different outcomes than an interview, as it enables participants to build on the responses and ideas of others, which increases the richness of information gained (Kontio, Bragge & Lehtola, 2008). Moreover, a focus group often generates more and different information than individual interviews do, because discussions between experts force participants to think even more clearly about their argumentation.
Second, focus groups can recreate real-world policymaking perspectives. By involving actors that regularly deal with climate policy, real-world conditions can be mimicked. A study by Adagha et al. (2017) that evaluated the use of a decision support tool for windmill placement in Canada by using focus groups explicitly mentions the added value for recreating real-world situations. This research mentions that this leads to more profound insights compared to individual in-depth interviews or expert meetings. Interaction can be observed that wouldn't be possible otherwise.
Finally, an often-mentioned advantage of focus groups is the possibility to observe a large amount of interaction and information of multiple people in a short period of time. This makes a focus group a quick and easy way to obtain data (D. L. Morgan & Krueger, 1997).

5.2.2 Disadvantages and risks of using focus groups

Next to its advantages, the use of focus groups also poses several risks and disadvantages. These risks potentially limit the validity and outcomes of this research. A big difference between focus groups and other qualitative research methods is the necessity to bring multiple people together at the same time. As focus groups consist of at least three people, there is a risk associated with not finding (enough) people to set up a focus group. Section 5.3.4 describes the setup of semi-structured interviews, that were conducted as not all participants could be brought together in focus groups.
A second risk is finding the right people for the focus group. A focus group within this research would be most effective when conducted with experts that have experience within the domain of climate policy. However, as this limits the pool of candidates, it is harder to find the right group composition. Due to the limited time and resources of this research, the objective is to hold focus group meetings within organisations that are active on climate policy. This entails that the participants of the focus group are all from the same organisation. This potentially leads to a bias of results as they might share the same vision on certain issues. Furthermore, it might mean that it becomes harder to generalise the results of multiple focus groups. On the other hand, it could also pose the advantage that the participants have been in a group discussion before, leading to a more smooth process. Participants might also be more willing to share their thoughts and opinions if they already know each other.
The advantage that the Y-factor can facilitate discussions, also poses a risk. Kontio et al. (2008) state that group dynamics are a hard-to-control variable in a discussion. The role of the moderator is very important to steer the discussion on the topics that he wants to discuss. Even though a focus

group might seem loose and unstructured to the participants, it is vital that the structure is considered beforehand and managed during the discussions. A final risk associated to focus groups is the short period of time in which all people need to be able to express their thoughts and opinions. If the focus group consists of 5 people and the focus group takes 1,5 hour including an introductory presentation, this means that the participants might only have 10 minutes to express their view on the Y-factor tool.

Table 5.1: Advantages and risks of using focus groups

Advantages	**Risks**
+ Generate discussion, leading to more and new information	- Finding (the right) participants
+ Recreating real-world situations	- Bias of focus group within one organisation
+ Observe a lot of information in a short period of time	- Hard to control group dynamics
	- Too short amount of time to let all participants express themselves

5.3 Content focus groups

This section describes the content of the focus groups. First, the necessary conditions are be described with regards to the number of people, the required number of focus groups, the duration and time planning. Table 5.3 provides a summary of the criteria. Hereafter, the content of the focus groups is discussed. In this study, the focus group is concluded with a questionnaire, which is discussed in subsection 5.3.3.

5.3.1 Practical setup focus groups

Focus groups can be of different sizes, but the number of participants can strongly influence the discussion and resulting outcomes (Richard A. Krueger & Casey, 2014). With too many participants, there is a risk of participants not being able to fully express themselves. With too few participants, the challenge of starting a fruitful discussion is larger. For non-commercial focus groups consisting of people with expertise on the to be discussed topic, a group of five to six people is recommended (Richard A. Krueger & Casey, 2014). However, focus groups can be organised from a group size of three (Kontio et al., 2008).To reach data saturation, three to six focus groups are adequate (Onwuegbuzie, 2018). Focus groups can be pre-existing groups, such as a group of colleagues (Onwuegbuzie, 2018), as long as there is suffi-

cient room for discussion.
A key aspect for enabling a fruitful focus group meeting is the presence of a moderator, who is responsible for structuring and promoting the discussions, making sure all the relevant information is obtained and everybody can have a say in the discussion. The role of the moderator is a demanding and challenging one (Richard A Krueger, 2002), especially within larger groups.

5.3.2 Selection of participants

The Y-factor focuses on providing information on a broad spectrum of carbon abatement options and is unique because it allows for cross-sectoral comparisons. This broad view on carbon abatement options for policymaking is mainly relevant for governmental organisations, or organisations advising public policymakers. This is confirmed by Turnpenny, Haxeltine, Lorenzoni, O'riordan and Jones (2005) who mention that governments are at the heart of providing guidelines on how to approach climate change. This helps to scope the type of organisations to approach for testing the Y-factor tool. For this research, the focus groups and interviews are therefore held at organisations that regularly deal with carbon abatement policymaking. These could be either public organisations, like the Ministry of Economic Affairs or private companies, such as consulting firms advising public organisations.

In the end, policymakers and policy advisers from five different organisations were found that were enthusiastic to provide their view on the process of making climate policy and how the Y-factor could fit in. The list below shows that:

- All participants are either public policymakers or policy advisers
- All participants are active within the domain of carbon abatement
- All participants are living and working in the Netherlands
- There is a balance of starters and very experienced people that participated in the focus groups or interviews
- Five out of the seven participants have a background at a technical university.

Apart from the participants who are active within the public policy domain on climate, a focus group was conducted with TU Delft Students who are passionate for the energy transition. Table 5.2 provides an overview of the participants.

5.3.3 Focus group content

This section describes how the focus groups are organised from a content perspective. The focus groups have two main objectives:

Table 5.2: Focus group and interview participants

Participant	Organisation	Job Title
Jasper Meijering[1]	TU Delft	Engineering and Policy Analysis (student)
Anne Boijmans[1]	TU Delft	Engineering and Policy Analysis (student)
Lennard Pol[1]	TU Delft	Sustainable Energy Technology (student)
Martijn Blom[2]	CE Delft	Senior researcher on financial instruments
Reinier van der Veen[2]	CE Delft	Medior researcher on fuels and cities
Diederik Jaspers[2]	CE Delft	Senior researcher on energy saving
anonymous[3]	Kwink Groep	Junior advisor energy and climate
Lisa van Woerden[3]	Ministry of Economic Affairs	Policy officer Electricity
Gerdien van de Vreede[3]	VNG	Data and Monitoring Energy Transition

1: participants of first focus group, held at TU Delft
2: participants of second focus group, held at CE Delft
3: participants of semi-structured interview, see section 5.3.4

1. Testing how the Y-factor can assist the process of policymaking. A vital part of this objective is the validation of the hypothesis that the Y-factor is most suitable within the formulation and decision-making stage of the policy cycle.
2. Testing whether the Y-factor web tool works as envisioned beforehand and assessing it on the criteria that were formulated in chapter 4.

The enumeration below shows how the focus groups are structured in four parts. Also, a time indication is given. 10 minutes are not scheduled to allow for delay:

1. A presentation explaining the Y-factor and the objectives of the focus group **(10 min)**
2. Introduction of the Y-factor tool to the participants **(10 min)**
3. Group discussions **(50 min)**
4. Questionnaire **(10 min)**

Table 5.3: Setup Focus Groups

Type of organisations	Active in the public policy domain on climate
Number of focus groups	2
Number of participants per group	3
Duration	90 minutes

Presentation Y-factor

First, a presentation on the background and objectives of the Y-factor was given on the Y-factor objectives and on how the Y-factor must be interpreted. Furthermore, the objectives of the thesis research and the focus group were explained. After this presentation, the participants were given the opportunity to ask questions.

Y-factor tool introduction

This part focused on the familiarising the focus group participants with the tool. This was done with the objective to observe how the participants use the tool and to obtain feedback on possible improvements to make the tool easier to use. To facilitate this, screen recording software was used to record mouse movements.

Group discussions

This part of the focus group is the most important for getting results on how the Y-factor can be used by policymakers. The main objective is to facilitate discussions on topics that are related to climate policy and lie within the expertise of the participants in the focus groups. The goal is for the participants to emerge into a discussion together, whilst using the Y-factor to structure their thoughts and reasoning. The discussion was led by three cases (Figure 5.1). Appendix B contains a more detailed interview guide.

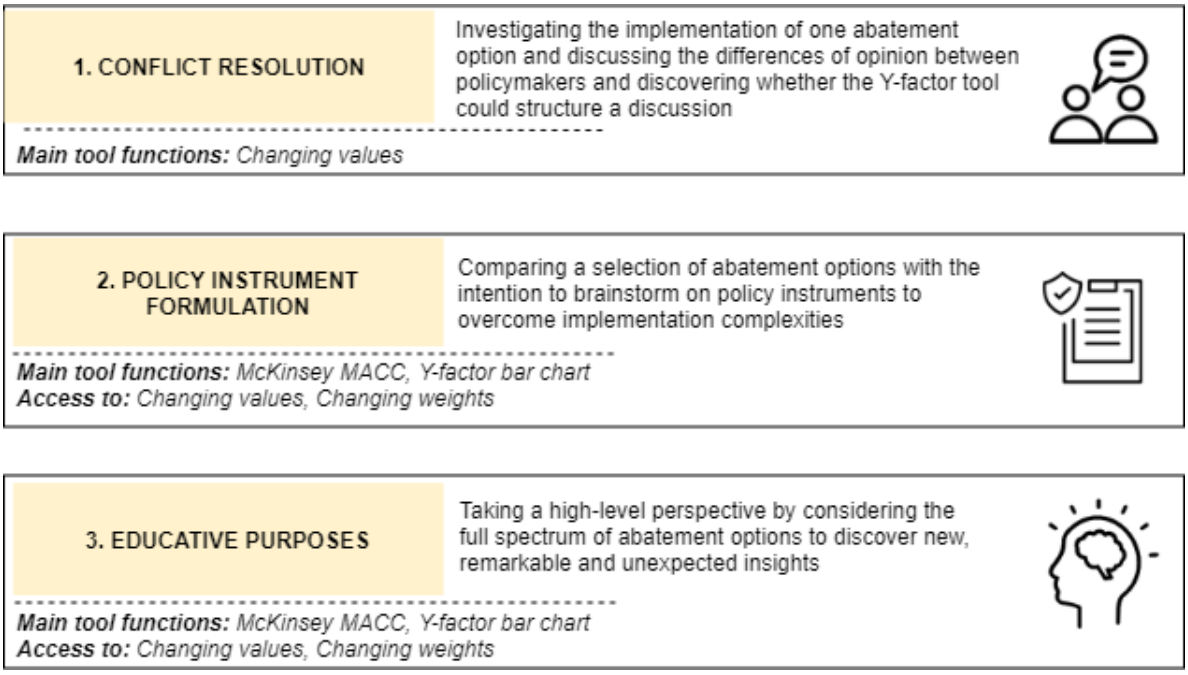

Figure 5.1: Focus group cases

Questionnaire

All participants of the focus group were asked to fill in a questionnaire in order to get a better-structured interpretation of their experience with the Y-factor tool in terms of usability and flexibility. The results of this questionnaire are used to test whether the conclusions drawn from the focus group observations are interpreted. Furthermore, this questionnaire requires participants to evaluate how they envision the use of the Y-factor to be most effect-

ive for policymakers. Appendix B contains the questionnaire and Chapter 6 displays the results of the questionnaire.

5.3.4 Semi-structured Interviews

As mentioned in paragraph 5.2.2, there are several risks associated with using focus groups as a research methodology. Within the restricted time of this research, it was not possible to bring all contacted policymakers together within a focus group. For this reason, several interviews were conducted as an addition to the focus groups in order to obtain sufficient information for testing the hypotheses from chapter 3 and the tool from chapter 4. These interviews are semi-structured because the objective is similar to that of the focus groups. The interviews are mainly conducted to get more insight into policymaking processes within the organisations that the interviewees work for and to test whether they would envision the Y-factor to be of use for their activities. The interview guide to support these interviews is presented in Appendix B and the results of the interviews are presented in paragraph 5.3.4 of the next chapter.

The interviewees were not familiar with the Y-factor beforehand and were given only little prior information to ensure an open mindset for the meeting. The meetings were performed face-to-face and as semi-structured interviews. This was done to allow the interviewees to speak freely and address more complex issues in more detail. All three interviews commenced with a PowerPoint presentation on previous Y-factor research, the objective of this research and the themes that were to be addressed during the interview. Hereafter, the interview revolved around three main themes:

1. Description of policy formulation and decision-making within their organisation
2. Discussion on the Y-factor method and its possible applicability for public policymaking
3. Possible improvements on how the Y-factor could be made more suitable for public policymaking (or other applications)

5.4 Conclusion

This chapter investigated the following research question:

"How can the applicability of the Y-factor tool in carbon abatement policymaking be tested in focus groups?"

Testing the applicability of the Y-factor (tool) for policymaking requires a qualitative approach, because it is a fairly new method and unrestricted input from policymakers in the field is required. Their answers are most valuable when not restricted by quantitative methods, such as surveys. The

choice for using focus groups as a methodology, origins from the intention to recreate real-world policymaking situations and generate discussions on these topics within the focus group.

Apart from the generation of discussions, which can generate more and deeper insights than one-on-one interviews, another advantage of using focus groups is that a lot of information can be observed in a short period of time.

The focus groups that are conducted for this research consist of three people. A relatively small group size was picked to allow for diving deeper into certain topics that require more attention. In total, two focus groups were organised, of which one was organised at the TU Delft with students, and the other at CE Delft, which is an organisation that provides advice to public policymakers. Three semi-structured interviews were conducted with two policymakers (one from the Ministry of Economic Affairs, one from the Association of Local Governments) and a consultant at Kwink Groep.

6 Results

This chapter tests the conclusions and deliverables from chapter 3 and 4 by conducting interviews and focus groups as specified in chapter 5 The sub-question that this chapter answers is the following:

"How do policymakers value the contribution of the Y-factor (tool) for carbon abatement policymaking?"

In total, three focus groups and two interviews were conducted. This chapter touches upon each of the interviews and focus groups separately, whilst highlighting the most relevant (with regards to the aforementioned sub question) quotes and conclusions. The chapter ends with a conclusion that combines these conclusions into an overarching conclusion with subsequent recommendations.

6.1 Focus groups

The conclusions are structured on content, rather than on time, and might therefore be extracted from different parts of the focus group. Some of the mentioned points are supported by quotes, recognisable by the quotation marks before and after the sentence. It must be noted that the focus groups were conducted in Dutch, so the highlighted quotes are translated into English.

6.1.1 TU Delft

This focus group was conducted at the TU Delft with three master students. One student from the program Sustainable Energy Technology and two students from the Engineering and Policy Analysis master program. All three students have an above-average interest for the energy sector, which they express both during and outside of their studies. Compared to the other focus group that is discussed hereafter, this focus group paid relatively more attention to whether the tool was functioning properly and interpreted well. After this focus group, minor adjustments were made to the tool before the other focus group was conducted. However, as these changes were so minor, it is highly unlikely they influenced the outcomes of the other two groups.

Opinions and possible improvements on the Y-factor and Y-factor tool

Opinions on and suggestions for further development of the Y-factor

- The participants mentioned that a substantial basis of knowledge on different abatement options is required to understand and properly use the Y-factor. They highlighted that expertise on an abatement option is needed to be able to say something about all twelve barriers determining the Y-factor score.
- The participants found it hard to clearly distinguish all twelve factors. They advised to provide more detail in the barrier names, or to give a clear explanation in the Y-factor tool.
- One participant addressed that he would like to show larger differences between the factor scores and that it might, therefore, be nice to consider changing the 3-point scale into a 5-point scale.
- The Y-factor provided the participants with new and relevant information that they were not aware of beforehand. This can be illustrated by the following observation: "why is there such a difference between different types of sustainable driving? - Ah, when I look at the values and explanation, it makes sense".

Opinions on and suggestions for further development of the Y-factor tool

- The participants mentioned that it would be an addition to provide the Y-factor scores in table form too. In this way, the scores might become more comprehensive.
- Currently, the tool is designed in a way that the checkbox list with all abatement options is always on the screen. The participants addressed that this might not be necessary as this list is only used in the beginning when filtering the relevant options.
- The participants mentioned that they like the Y-factor MACC crossover and thought that it could be a very useful tool because it contains a lot of information. However, it is feared that, due to its bottom position on the page, it won't be used frequently.
- A possible improvement would be to always be able to show the reference curve and to be able to compare that one to the one that was created by changing weights and values.
- With changing the weights, a participant mentioned that it is important to have a time scope in mind. Category values might be very dynamic: "currently, local resistance is very active. However, in the long run, it is more likely that some resistance might fade, whereas other complexities might remain or even worsen".

Envisioned applicability of the Y-factor for policymaking

The participants were asked how they would foresee the Y-factor be used for carbon abatement policymaking, after being introduced to the concept of the policy cycle.

- It was argued that the Y-factor would be most suitable in the early stages of the policy cycle. In the policy formulation and policy decision-making stage, the Y-factor could provide a nice framework to generate a general idea on the associated implementation complexities.
- "If the Y-factor were to be used for policy evaluation, a pre-assessment with the Y-factor needs to be done as well." They mutually agreed that otherwise, the Y-factor would not be suitable for evaluation.
- The participants thought that for policymakers, it is also important to take into account what the societal side effects would be. Knowing the associated co-benefits, such as the creation of new jobs, would constitute an extra reason for choosing a certain abatement option. Also, on the other side of the spectrum: associated disadvantages need to be known beforehand too.
- The possible added value of the Y-factor for education purposes was mentioned. The Y-factor could raise awareness for students, but also for policymakers, on how to judge the applicability and suitability of policy instruments to lower carbon emissions.

Focus group observations

- There was little to no discussion when values of a specific technology were altered. This could be attributed to the fact that the participants thought they were not knowledgeable enough to change the values.
- The discussion was most vivid when comparing different abatement options with each other.
- When asked to compare technologies, the participants felt the urge to change values of abatement options relative to one another.
- At first, two of the three participants interpreted the use of weights in the wrong way, as they wanted to change the weights specific for a certain abatement option.

Main takeaway TU Delft focus group

The focus group session at the TU Delft was particularly useful for further improvements on the Y-factor tool. Misinterpretations of the Y-factor were observed and improved specifications and explanations were suggested to improve the understanding of both the twelve Y-factor barriers and the carbon abatement options for policymakers that have no or few experiences with the Y-factor or the McKinsey MACC. As critical people made active use of the tool, new suggestions were given with regards to the layout and setup of the tool. This showed that some aspects of the tool were used far less, because of their position on the web page, not necessarily because of its limited purpose. For policymaking, the hypothesis was confirmed that the Y-factor could be most useful for the policy formulation and policy decision-making

stages. Furthermore, the Y-factor was seen as a potentially interesting tool for evaluation, provided it is used ex-ante as well.
The participants were hesitant to use the tool at first, but grew more confident further on in the focus group. This led to increased interaction with the tool, which in turn stimulated discussions between the participants. These discussions mainly originated from the comparison of abatement options and the alteration of Y-factor values. The weights did not generate discussion.

6.1.2 CE Delft

CE Delft is an independent research and advisory agency, specialised at the development of innovative solutions for climate-related issues. This focus group was conducted at the CE Delft office with three of their employees: Martijn Blom, Diederik Jaspers and Reinier van der Veen. See Table 6.1

Table 6.1: Researchers CE Delft

Martijn Blom	Senior researcher on financial instruments
Reinier van der Veen	Medior researcher on fuels and cities
Diederik Jaspers	Senior researcher on energy saving

The most conclusions were drawn when the participants emerged in a discussion on what phase of the policy process the Y-factor could be of use and on how the Y-factor could be tweaked and improved to be most effective for drafting policies. The next paragraph mentions and structures the most relevant conclusions of the focus group.

Opinions and possible improvements on the Y-factor and Y-factor tool

Opinions on and suggestions for further development of the Y-factor

- The participants would not necessarily advice to change the Y-factor scale from 3 to 5. "It is questionable whether further detailing the scale, would add value and still manage to be specific enough about the complexity."
- For the Y-factor to be suitable for policymakers, the participants mentioned that scores for abatement options need to be validated by more experts. This would make the Y-factor more trustworthy. If more experts would provide their expertise, the participants encouraged to show a confidence interval per factor score, or give the possibility to display the underlying expert information per factor.
- Using the Y-factor as a reference curve would be very interesting when scoped on a national level. "This would be more valuable, than on an international level, because of laws and regulations, which constitute

a large part of the implementation complexity, are determined on a national level."

- The participants were most critical on the formulation of several abatement options. They were wondering whether the options were scoped by current implementation complexity or estimated complexity until 2030?

Opinions on and suggestions for further development of the Y-factor tool

- The participants stated that it is important for the tool to be used correctly because otherwise, it could lose its reliability. The tool would be most suitable when used by a consultant, knowing the ins and outs of the Y-factor and not by the client to whom advice is given. This is where the Y-factor tool could be at its best: the creation of a new curve that explains the current complexity of a situation. This curve could then be conveyed to the client. If the client starts using the tool by itself, weights and new values might not be used appropriately.
- One of the participants mentioned that the weights create a sense of reliability, which can't be ensured.
- It was advised to add a reset button for when values have been altered. Just like the reset button for the weights.
- It was recommended to add a possibility to show why and by whom the scores were given.

Envisioned applicability of the Y-factor for policymaking

The participants were asked how they would foresee the Y-factor to be used for carbon abatement policymaking, after being introduced to the concept of the policy cycle.

- The participants stated that the Y-factor would mainly be suitable for policy formulation and policy decision-making. When it comes to formulation, the Y-factor could provide a high-level overview and could be used on the front end, to convey a message on implementation complexities and choices that were made to move away from the reference curve. For decision-making, the participants highlighted that it could be a nice way to compare different options with each other.
- If the Y-factor tool were to be used for evaluation purposes, the participants mentioned that it should also be used before the implementation of a policy instrument (ex-ante and ex-post) to guarantee reliable conclusions.
- The Y-factor would be most relevant after using the marginal costs curves. The participants envisioned costs to always remain the most decisive factor in determining climate policy.
- When asked for possible applications for the Y-factor, a participant mentioned that it could have been very useful during discussions and negotiations of the Dutch 'klimaatakkoord'. For these negotiations,

a different dashboard was used, but this lacked an integral way of evaluating options.

Focus group observations

During the focus group, the following observations were done:

- The barriers were interpreted wrong: resistance from the local environment was interpreted as a part of the behaviour category, instead of the multi-actor category.
- Initially, changing weights were used to lower the importance of a factor on a specific technology instead of the entire context.
- The discussion was most vivid when different abatement options were compared. No discussion arose when option specific Y-factor values were altered. It was mentioned that this should not be a point of discussion, because they think that the discussions would be more relevant if the Y-factor values would be agreed upon.

Main takeaway CE focus group

The focus group at CE Delft was particularly useful for discussing the applicability of the Y-factor for policymaking. With regards to the policy cycle, the hypothesis was confirmed that the tool would be most useful in the policy formulation and policy decision-making stages. If the Y-factor were to be used for ex-post policy evaluation, it needs to be used ex-ante as well.

Especially for the comparison of different abatement options, the tool is regarded as very interesting, because it provides a framework that can rank the abatement options on the same criteria. The tool could be used for distribution of SDE+, or as a starting point for broad discussions as conducted for drafting the Dutch 'klimaatakkoord'. With regards to the functions of the tool, the advice is given is to ensure that the tool is used in the correct manner. Changing weights and values are interesting functionalities, provided that they are used properly. When users without the necessary experience use the tool, it could suggest a form of reliability that is in fact not present.

The Y-factor could be effective when complementary to the MACC, but the focus group participants did state that costs will always remain the primary consideration for drafting policies. Therefore, the Y-factor can be expected to be used after MAC-curves.

6.2 Questionnaire results

All participants of the focus groups were asked to fill in a questionnaire after the session. See paragraph 5.3.3 for the motive and Appendix B for the full questionnaire. The questionnaire is structured in three components and the results are, therefore, structured similarly. First, the usability and

flexibility of the Y-factor tool are discussed (6.2.1). Hereafter, the assessment of the different functions of the tool is shown (6.2.2). The final part of the questionnaire focuses on how to apply the Y-factor for policymaking (6.2.3). The questionnaire was filled in by all of the six focus group participants. As this is only a small sample, no statistical significance can be given to the results. The main objective of this questionnaire is to confirm whether the observations from the focus group comply with their answers in the questionnaire.

6.2.1 Usability and Flexibility

The design of the Y-factor tool is assessed on the System Usability Scale (See 4.2.2). Table 6.2 shows the results of this questionnaire. Note that the questions are translated to Dutch for the participants of the focus group.

Table 6.2: SUS results

no.	System Usability Scale statements (ranked 1 to 5)	Mean (std. dev.)	Criteria
1	I think that I would like to use this tool frequently.	3.67 (0.51)	All factors
2	I found the tool unnecessarily complex.	1.83 (0.75)	U1, U2
3	I thought the tool was easy to use.	4.00 (0.89)	U1, U2
4	I think that I would need the support of a technical person to be able to use this tool.	1.67 (0.82)	U2
5	I found the various functions in this tool were well integrated.	4.33 (0.52)	U1
6	I thought there was too much inconsistency in this tool.	2.00 (1.10)	U1
7	I would imagine that most people would learn to use this tool very quickly.	3.83 (0.41)	U4
8	I found the tool very awkward to use.	1.67 (0.82)	U4
9	I felt very confident using the tool.	3.83 (0.75)	U1, U3, U4
10	I needed to learn a lot of things before I could get going with this tool.	2.33 (1.21)	U4

Three questions regarding the usability - flexibility trade-off are added to the questionnaire. These questions are relevant for assessing the user experience of the Y-factor tool but are not part of the System Usability Score.

no.	Flexibility - Usability statements (ranked 1 to 5)	Mean (std. dev.)	criteria
11	I could easily correct myself after making an error.	4.17 (0.75)	U5
12	The Y-factor is engaging to work with	4.17 (0.75)	U3
13	It was easy to navigate between different Y-factor functions.	3.17 (1.47)	F1

The final usability score is calculated as seen in the list below (Brooke, 1986) and should be interpreted as shown in table 6.3

1. For each of the odd-numbered questions, subtract 1 from the score.
2. For each of the even-numbered questions, subtract its value from 5.

3. Take these new values, and sum the total score. Multiply this by 2.5.

Table 6.3: Interpretation System Usability Score (Brooke, 1986)

SUS Score	Grade	Adjective Rating
100	-	MAXIMUM
> 80.3	A	Excellent
68 - 80.3	B	Good
68	C	Okay
51- 68	D	Poor
< 51	F	Awful
0	-	MINIMUM

Using the scores from Table 6.2 and implementing this in the calculation from the list below the table, the following score can be calculated:

$$\sum((3.67-1)+(5-1.83)+(4-1)+(5-1.67)+(4.33-1)+(5-2)+(3.83-1)+(5-1.67)+(3.83-1)+(5-2.33))*2.5=75.4$$

As assessed by the six participants of the two focus groups, the tool is given a usability score of 75.4 (0-100 range). This score confirms the observation made during both focus groups that the participants were relatively confident using the tool and predominantly managed to use the tool in the way they wanted.

6.2.2 Assessing Y-factor functions

Table 6.4: Y-factor functions assessment

Y-factor tool function	Useful (1 to 5)	Easy to use (1 to 5)
Attaching weighs to a factor score	4.17	4.5
Adjusting factor values	4.5	4.17
Filtering abatement options	4.17	4
Toggle level of detail	3.5	4.33
Providing information per abatement option	4.67	3.67
McKinsey MACC Scatterplot	4.33	4.17

Several conclusions and suggestions can be drawn from the questionnaire:

- The information that supports of the Y-factor barrier scores is important. However, the structure of the shown information could be clearer and more expert opinions are recommended.
- The McKinsey MACC crossover provides interesting insights into the abatement potential of the options, but could be facilitated with clearer axis labels.
- The toggle level of detail function influences both the weights and the graphs. It is therefore recommended to add this as a button at the weights as well.

- Changing factor values are seen as more useful than attaching weights. A potential reason for this, which was mentioned during the CE focus group, is that changing weights requires more information about the entire context in which a policymaker operates. This differs greatly from deciding on a different implementation complexity score for a specific technology.

6.2.3 Y-factor for policymaking

All focus group participants were asked how they would foresee the Y-factor to be used for policymaking. They were asked whether they would expect the Y-factor to be able to generate discussions, whether the Y-factor would be able to generate new and relevant insights, how the Y-factor could be improved to be of more value and finally, where in the policy cycle the users would envision the Y-factor would be most valuable. Figure 6.1 shows a bar chart of the different stages of the policy cycle and per stage how many focus group participants would foresee the Y-factor to be valuable. Below the most relevant conclusions are highlighted.

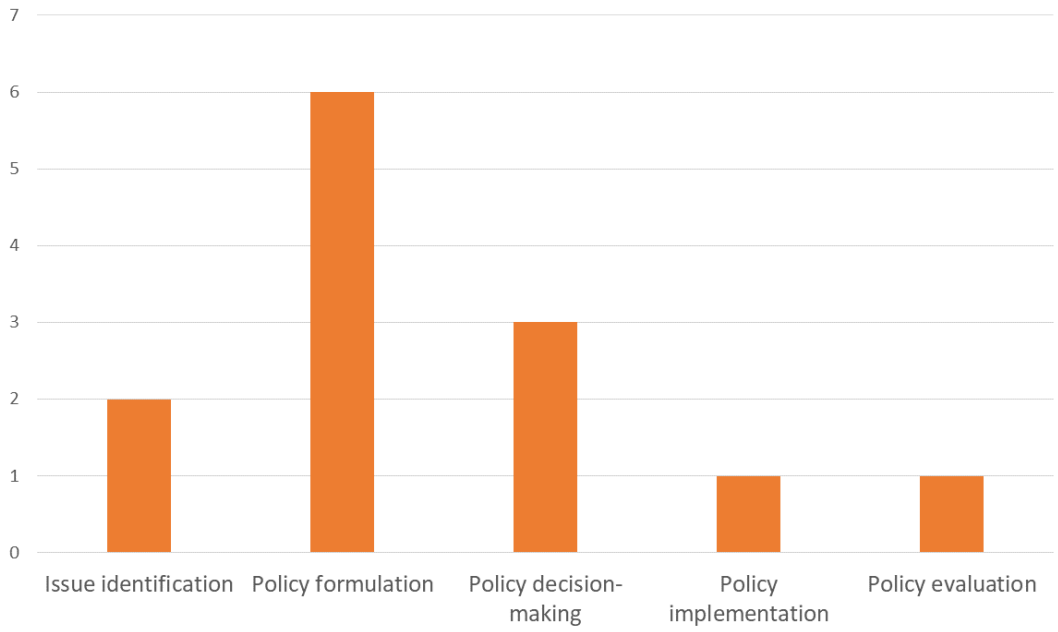

Figure 6.1: Using the Y-factor in the Policy Cycle

- It has the potential to show interdependences between different factors that are often not taken into account. Furthermore, it helps to compare technologies, in a structured way that could not be done before.
- Regarding the generation of discussion, the participants agree that the Y-factor has the potential to generate and facilitate a structured discussion. To improve its suitability, the factor barriers need to be specified better and the substantiation of how the scores were determined needs more elaboration.

- Considering the policy cycle (figure 6.1), the participants mention that the Y-factor is most useful for policy formulation. Remarkably, both focus groups discussed the Y-factor for policy evaluation, but when filling in the questionnaire, only one participant acknowledged the Y-factor's suitability for evaluation purposes.

6.3 Interviews

Apart from the focus groups, three semi-structured interviews are conducted: at the Dutch Ministry of Economic Affairs and Climate, at the Vereniging van Nederlandse Gemeenten, and at Kwink Groep. These interviews were conducted to gain more insight into the public policy decision making related to climate, and on how the Y-factor could assist this process. Compared to the focus group meetings, the interviews focused less on the usability of the Y-factor tool, but more on the applicability of the Y-factor for policymaking.

The next sections discuss the outcomes of the three interviews. All interviewees specifically addressed that their comments should be regarded as a personal opinion and should not be seen as an official viewpoint of the organisations to which they are affiliated. The interviewee at Kwink Groep wished to be kept anonymous.

6.3.1 Gerdien van de Vreede - Vereniging van Nederlandse Gemeenten (VNG) - *Data & Monitoring Energy Transition*

Drs. ir. Gerdien van de Vreede, from now on referred to as Van de Vreede, has been working at VNG since 2018 and focuses specifically on facilitating municipalities with the disconnection of neighbourhoods from the gas network. Before, she worked for TKI Urban Energy and CE Delft.

Policymaking within municipalities and at VNG

- Van de Vreede mentioned that distribution mechanisms and policies are primarily focused on limiting costs and increasing revenues (both on a municipal and national level). Other forms of implementation complexities are considered but are not taken into account in a structured manner.
- "The complexity of implementing options differs enormously per municipality". Especially the municipal transition from gas to electric heating has varying implementation complexities.

According to Van de Vreede, the Y-factor could have added value for drafting regional strategies.

Applicability of the Y-factor for public policymaking

- Van de Vreede expected the Y-factor to be suitable for structuring and generating discussions on why and how to implement certain abatement options. Furthermore, she confirmed that the Y-factor addresses the most important complexities.
- Van de Vreede expected the tool to be usable, provided that it should be used by the right person in the right way. With changing values and weights, the tool suggests certain objectivity that is, in fact, not present. She recommended avoiding uneasy discussions on whether the value for an abatement option should be 0,1 or 2. Discussions on the best option to implement and what complexities to consider are more valuable.
- What van de Vreede did not like about the Y-factor is that the scores were given based on qualitative interpretation, consequently given an absolute score, to be used for qualitative measures afterwards. This too gives the idea of certain reliability that is not present.
- Van de Vreede especially valued the MACC crossover, due to the high information density in the graph, whilst remaining easy to understand. In her opinion, the three most crucial aspects to consider when drafting climate policies are present in this bubble chart.

Recommendations for Y-factor improvement

- Van de Vreede mentioned that she thinks that a 3-point scale does not allow for enough variation. She recommends using a 5-partite scale or be able to mention that a certain factor has such a high complexity, that it could be given a 'knock-out' value.
- Van de Vreede expected the Y-factor to be of most use for consultancy organisations, as they prefer working with visualisations and graphs. Within public organisations, often textual explanations are preferred.
- She recommended the creation of a manual on how (not) to use the Y-factor. The Y-factor can be used wrongly, as the interpretation of weights for example. With a manual or better explanations within the tool, this could be prevented.
- Laws and regulations are very country-, or even municipality-, specific, and have a high impact on the scores of the Y-factor. Van de Vreede recommended to try and incorporate this into Y-factor barriers.

6.3.2 Lisa van Woerden - Ministerie van Economische Zaken en Klimaat - *Policy Officer Electricity*

Ir. Lisa van Woerden, from now on referred to as Van Woerden, has been working at the Ministry of Economic Affairs since 2017 and currently works as a policy officer for the electricity department. Her main area of expertise

lies with coal factories. She is a graduate from the faculty of Technology, Policy and Management at the TU Delft.

Policymaking at the Ministry of Economic Affairs

- Costs are very central in the approach of the Ministry of Economic affairs towards the formation of public policy. SDE+ subsidies for renewable energy are distributed based on marginal costs. Van Woerden mentioned that the government can be held accountable by its electorate, who pay most attention to financial impact.
- The Ministry of Economic affairs performs extensive assessments when new the implementation of new technologies are considered. Similarly to the Y-factor approach, many different aspects are taken into account, but there is no generalised method used to assess abatement options. Therefore, she values the Y-factor.
- Van Woerden advises incorporating a political factor into the Y-factor, as this can be a dominant force in decision-making. She mentions that (the lack of) permits are often hampering the implementation of new technologies.
- Van Woerden mentioned that policy instruments are evaluated based on effectiveness and efficiency (*Dutch: doelmatigheid en doeltreffendheid*).

Applicability of the Y-factor for public policymaking

- Van Woerden expects the Y-factor to be useful for the department of climate at the Ministry, where overarching climate goals are formulated. Furthermore, the Y-factor could be used to determine what options can be implemented in the short run to make sure enough reductions are made before 2020.
- Van Woerden especially liked the MACC crossover and easily managed to draw conclusions from it. She likes that three valuable pieces of information are contained within one graph for 24 different options.

Recommendations for Y-factor improvement

- Van Woerden advised incorporating a laws and regulations barrier into the Y-factor as this can really hamper implementation.
- Van Woerden mentioned that many policy officers do not always know how to interpret similar graphs containing a lot of information. At the Ministry, policy offers are used to texts instead of visualisations. She would, therefore, recommend constructing a manual.

6.3.3 Kwink Groep - *Consultant*

The interviewee has been a consultant for Kwink Groep since September 2018 and primarily works on topics of climate and energy policy, which is one of the four main topics in which Kwink Groep operates. 95% of Kwink Groep clients are from the public sector (on a local, provincial and national level).

Climate policy at Kwink groep

- The interviewee mentioned that Kwink uses a slightly altered version of the policy cycle to structure the process of climate policy into four stages: plan development, plan execution, monitoring of progress and the final phase considers learning & justifying.
- For many people and organisations, climate change and the formulation of climate policy is very complex. The interviewee mentioned that she is convinced that climate policy should always be tangible and formulated SMART, in order for governmental agencies to have a clear set of actions[1]. By doing so, monitoring and evaluation are also facilitated.
- Within the phase of policy formulation, Kwink makes use of the 'Theory of Change' concept. When formulating a policy, objectives are generated and subsequently, certain conditions have to be met to fulfil these objectives. These conditions are distinguished into four categories: technology, business case, public acceptance and laws + regulations. To meet these conditions, policy instruments are linked to the mentioned conditions.

Applicability of the Y-factor for public policymaking

- The interviewee mentioned how, by structuring complexity into categories, the Y-factor could help to overcome a difference of opinions that policymakers hold.
- Using the Y-factor and especially changing factor values or weights requires time and expert knowledge. Therefore, she would not envision the Y-factor to be used on a local level, but either to be used by consultants/ research institutes or on a more national level.
- Her first thought on the Y-factor applicability was that it could have added value as a monitoring instrument. A baseline could be created on the complexity of implementing a certain technology and this could be monitored throughout the execution of a policy using the Y-factor.
- When changing values of the different Y-factor barriers and weights, the reliability of the tool might fade. The interviewee envisioned that the Y-factor might therefore be more relevant as a reference curve, provided that concrete actions could be linked to the barriers.

1 Specific, Measurable, Achievable, Realistic and Time-bound

Recommendations for Y-factor improvement

- When starting up the tool, a lot of information and many technologies are shown. The tool might become more tangible and clearer if only a few technologies show in the beginning, and an option is provided to show all technologies at once.
- The interviewee mentioned that she found it hard to place two complexities into a Y-factor category: public acceptance and laws + regulations. She would recommend to either formulate some Y-factor categories more clearly or consider adding an extra barrier.
- Even though she realised it might be hard, the interviewee mentioned that it would help to think of a policy instrument toolbox that could link to certain Y-factor categories, and in this way facilitate policymakers.

6.3.4 Main takeaway interviews

For the semi-structured interviews, a different approach was taken compared to the focus groups. More findings were obtained on the policymaking and policy advising processes within the VNG, Kwink Groep and the Ministry. Worth mentioning is that all interviewees mentioned that laws and regulations on a national level can highly impact the Y-factor scores. This gives rise to the idea of either incorporating this into one of the twelve existing barriers or scoping the entire Y-factor on a more national level.

Furthermore, the interviewees value MAC-curves, because in the public sector most decisions are made based on financial evaluations. The combination of the Y-factor with the MACC was therefore appreciated. With regards to the applicability of the Y-factor, van Woerden mentioned that it can be of a great benefit at the Ministry to structure and visualise implementation complexities. Van de Vreede is a bit more sceptical due to the qualitative nature of the Y-factor and the small range of the Y-factor values (of 0,1 and 2).

Another recurrent topic during the interviews is the comprehensiveness of the Y-factor. The interviewees mentioned that the Y-factor contains a lot of information, but also requires a great deal of knowledge to make use of the method. To ensure that the Y-factor (tool) is used in the correct manner, users need to be informed well on how to use it.

6.4 Analysis and conclusion

The Y-factor tool as described in chapter 4, was presented to nine people from five different organisations. This was done to answer the following sub question:

How do policymakers value the contribution of the Y-factor (tool) for carbon abatement policymaking?

Six out of the nine people participated in a focus group and the other three were introduced to the Y-factor through a semi-structured interview. All participants in this research were asked for their opinion on the Y-factor, the Y-factor tool and its applicability for policymakers or policy advisers. This led to many opinions, information and advice on the Y-factor and ways to improve it. Some information that was collected across the different interviewees show similarities, but other pieces of advice seem contradictory. Furthermore, not all comments are directed towards improvement for the Y-factor (tool), but are inherent to the McKinsey MACC, which is underlying to the design of the Y-factor. This conclusion analyses, categorises and, where necessary, filters the collected knowledge. This is structured by the following questions:

1. How can the Y-factor tool be used most effectively?
2. Who are potential Y-factor users?
3. Where in the process of policymaking is the Y-factor best of use?
4. How can the Y-factor tool be improved?
5. How can the Y-factor method be improved?

Table 6.5 provides an overview of the conclusions on these questions, which is more extensively elaborated in the paragraphs below the table.

Table 6.5: Conclusions chapter 6

Question	Conclusions
How can the Y-factor tool be used most effectively?	The tool can be used to create a reference curve, in order to guarantee reliable information. This curve would be most valuable when scoped on a national level
	The Y-factor can educate policymakers to improve their understanding of the complexity that is associated to different abatement options
	The tool can be used to generate and structure discussions for the comparison of abatement options, but not for discussions on how to score factor barriers
Who are potential Y-factor users?	The Y-factor should be used by knowledgeable people that are aware of the exact purpose of the Y-factor
	If the Y-factor were to be used by unprepared policymakers, there is a risk of misuse and loss of reliability
Where in the process of policymaking is the Y-factor best of use?	All interviewees envision the best application of the Y-factor when used for policy formulation
	Possible application for monitoring and evaluation, if a baseline is created ex-ante
How can the Y-factor tool be improved?	Reset button for factor values
	Automatic filtering with clicking checkboxes
	Showing more background information on abatement options
	Showing Y-factor values in a table
	Creating a manual on how to use the Y-factor tool
How can the Y-factor method be improved?	Include a factor for laws and regulation
	Specify factor scores on a 5 or 7-step scale

How can the Y-factor tool be used most effectively?

One of the reasons for creating the Y-factor tool is to allow for policymakers to **get new insights into the implementation complexity of different abatement options**. Moreover, insights are given on what would happen when certain factors were considered harder to overcome than others (with changing weights), or to facilitate discussion on the right topics. The tool would then facilitate 'playing around' to generate new insights and discussions. When asked for the optimal application of the tool, different ideas were put forward by representatives of three organisations (CE Delft, VNG, Kwink). They were afraid of the Y-factor to lose its **reliability** when weights and barrier scores would be altered without a very strong basis. This is remarkable as the tool was developed to stimulate interaction by policymakers with the Y-factor for them to get a better grasp of the relative importance of complexities for certain abatement options. It was intended to let users change weights and values to see how this affects the Y-factor curve. The fear of the loss of reliability made the policymakers more sceptic on this way of applying the tool. A reflection and subsequent recommendations on how to stimulate interaction are given in chapter 7.

The interviewees that addressed this topic, all agreed that a **core strength of the Y-factor tool would be to create a reference curve** for the situation at hand that would subsequently be used as a reference for further policymaking discussions. As Van der Vreede (VNG) mentions: "It would not be fruitful to have a multi-person discussion on whether a factor should have value 0,1 or 2". **More discussion can be generated on the comparison of different abatement options and the choice for policy instruments.**

Second, the creation of Y-factor curves on a national level was addressed. Different than for marginal costs alone (as is the case with the MACC), the implementation complexity is more geographically bound. Mentioned at both VNG and Kwink was that even on a municipal level, large differences are present. However, using the Y-factor on such a small scale would be less relevant, concerning the size and impact of many of the abatement options that are considered. Moreover, most climate policy is formed on a national or supranational level. **Creating reference curves on a national level is preferred** by most interviewees. The main reason for this is that laws and regulations can differ strongly per country, which influences the complexity of implementation on multiple aspects. Furthermore, multi-actor situations are organised differently per country, the physical landscape differs and finally, most climate policy is formulated on a national level rather than supranational.

What are potential Y-factor users?

It was observed during the two focus groups and subsequently confirmed in the questionnaire that the tool is fairly easy to understand, to learn and to use. These factors should therefore not be limiting the target audience of the policy support tool. However, during the interview sessions with VNG,

TU Delft, CE Delft and Kwink Groep, it was recurrently mentioned that if the tool were to be used in a correct manner to get a representative result, it should be used by **knowledgeable people that are fully aware of what all (changes in) factor scores mean**. At CE Delft, it was suggested that a consultant could alter values and present this to the client as a reference curve, but that giving this tool to their client would not ensure the correct use. During the interview with Kwink, it was also addressed that their clients would be less interested in why to implement a certain option, but more focused on what actual instruments they have to implement.
For the facilitation of discussions, it is advised to involve someone with the knowledge of the possibilities that the Y-factor offers.

Where in the process of policymaking is the Y-factor best of use?

Within the framework of the policy cycle, most interviewees were relatively united on the positioning of the Y-factor. During the two focus groups, it was mentioned that the Y-factor tool could provide ex-ante insight into the complexities that need to be addressed by the to be formulated policy. The tool could, therefore, be used to ensure that every possible hurdle is thought of and addressed in the stage of **policy formulation**. When asked to think of applications in other phases of the policy cycle, the possibility of evaluation was also considered in the CE Delft and TU Delft focus groups. This would, however, only be relevant if an ex-ante assessment of the complexities was done as well. Notably, in the questionnaire, only one of the participants mentioned that the Y-factor could be used in the stage of evaluation. The interviewee from Kwink Groep suggested using the Y-factor for monitoring the effectiveness of a policy.par A challenge that lies ahead with further developing the Y-factor is the question of how the Y-factor could be used for the **generation of policy instruments**. When matching policy instruments with certain Y-factor barriers, more concrete advice could be delivered to policymakers. However, it is questionable if making a general toolbox of policy instruments would be feasible and if so, whether it would be realistic. The alternative would be to leave this out of scope and let policymakers address this discussion for policy instruments themselves, based on the complexities that are portrayed by the Y-factor.

Y-factor tool improvements

All participants were asked what they value about the Y-factor tool and what improvements they would suggest. During the interviews at the VNG, the Ministry of EZ and CE Delft, especially the **crossover between the McKinsey MACC and the Y-factor was appreciated**. The overall experience of the Y-factor tool use was positive too, as was confirmed in the questionnaire.

A few suggestions for improvement were made. First, the lack of a button to **reset the changes of factor values** was addressed. Other possible improvements that were addressed were: filtering abatement options without having to click submit (CE Delft), show the Y-factor values in a table (TU

Delft), provide extra information on why factors were scored as they are (CE Delft), showing fewer abatement options in the beginning for the sake of clarity (Kwink). A larger improvement, with regards to the usability of the tool, would be to make it easier to navigate through the different tool options. This could be done by creating a dashboard. This is further addressed in chapter 7 and Appendix A. A final improvement for the tool would be to better stimulate and facilitate interaction. The functionalities to account for more interaction (changing weights and values) are present, but were insufficiently used during the focus groups and interviews. Loss of reliability and representativity of the Y-factor scores were mentioned as a main cause for this. More interaction can either be stimulated by clearer explanations within the tool, a manual on how to use the tool, or better explanations and expectation management before using the tool.

Opinions on the Y-factor method

During the interviews and focus groups, not only feedback was given on the Y-factor tool, but also on the Y-factor itself on the choice of factor distinction, factor levels and abatement option scoping. With regards to the latter, this is not further discussed in this report as the abatement options were copied 1-on-1 from the McKinsey MAC-curve. The choice and segregation of the twelve Y-factor barriers were discussed extensively on two topics. First, during the interviews with van Woerden and at Kwink, the **increased complexity due to laws and regulations** was stressed. This is not incorporated as a factor, partly because different laws have an influence on different barriers. In chapter 8, further reflection on this factor is provided.

Secondly, it was questioned whether the Y-factor was specific enough with only three levels of scores per factor. Van der Vreede (VNG) was convinced that this was not the case, and at the TU Delft focus group, this doubt was shared. When this distinction was addressed at the CE Delft focus group, there was an understanding of this doubt. However, they envisioned that **specification to a 5 or 7-factor level** would lower the validity of the scores because the complexity would for many abatement options be too hard to indicate. My reflection on this topic is addressed in chapter 8. A final notion on this point by a participant of the CE focus group was that the Y-factor would become more relevant if more expert opinions would be collected on a 3-factor level and showing a confidence interval, rather than increasing the number of scoring categories to 5 or 7.

7 Conclusion and Recommendations

This chapter summarises the research and subsequently presents its conclusions. Hereafter, recommendations are given on how to continue Y-factor research, by highlighting possible improvements for the Y-factor tool, the Y-factor method and by addressing other fields for Y-factor application.

The binding agreements from the Paris agreement are proof that climate change is recognises and that national governments acknowledge the necessity of their role to tackle it. However, it could be argued that many governments are still not willing or able enough to take the necessary measures to mitigate the effects of global warming. Regularly, policymakers are confronted with the challenge of how to tackle climate change and how to contribute to meeting the goals that are set in various climate agreements. They are confronted with the question of what option to invest in and what policy instruments to introduce to meet these goals. In light of these, and similar questions determining a choice for investing in carbon abatement options, the Y-factor was developed.
The Y-factor approach works complimentary to marginal cost curves, such as the McKinsey MACC (Naucler & Enkvist, 2009). The McKinsey MACC ranks carbon abatement options based on their marginal costs in € per ton CO_2 equivalent. The Y-factor complements these curves by providing abatement option specific information on the complexities that are associated with its implementation.
The Y-factor has been developed to such an extent that 24 different abatement options were scored on their implementation complexities (by expert reviews) and consequently ranked in a bar chart. This chart and its underlying scores provide a good basis for addressing implementation complexities, but still show room for improvements on several aspects. This research investigated two of these aspects, which can be improved to widen the applicability of the Y-factor. Firstly, the Y-factor is relatively static and does not account for variations of complexity in varying situations. Secondly, it was investigated how the Y-factor could be effectively applied for policymaking.

7.1 Conclusion

This research used a design approach to develop a support tool and facilitate policymakers understand the complexities of the implementation of GHG reduction. This approach is used to answer the main research question that reads as follows:

In what way can the Y-factor be enhanced to make it suitable for use by policymakers within the process of the policy cycle?

The Y-factor's employability increased with the development of a support tool. This tool generates new insights and facilitates interactive discussions on the complexities of implementing abatement options. Consecutively, it can be used to construct national Y-factor reference curves to get more reliable insights on the context-dependency of complexities on a national level. This tool is especially useful during the early stages of the policymaking process, as the Y-factor can address the complexities of implementing abatement options on a high-level overview. This overview helps policymakers with a starting point for discussions on what policy instruments can be formulated to address the complexities hampering successful implementation.

The Y-factor illustrates forms of complexity that are dependent on and caused by multiple different factors. Even for a specific abatement option, the implementation complexities can differ per situation, and dependent on the context, the barriers to implementation vary from case to case. However, this research shows that these complexities can best be explained within the scope of national boundaries.

Concluding, there are three ways in which the Y-factor tool can be used, and it is important to make a clear distinction between the three to draw the right conclusions from the analysis. These three activities and their supporting functions are explained below and schematically shown in figure 7.1.

First, the tool can be used to generate insights into the different complexities that need to be dealt with by policymakers, and what these complexities mean for the subsequent implementation of abatement options. By changing weights of relative Y-factor barriers, changing the specific values of carbon abatement options and reading the expert background of the abatement options, policymakers can familiarise themselves with the information that the Y-factor provides. The objective of the Y-factor should, in this case, be to educate policymakers.

The second way in which the tool can be used is to generate and structure interactive discussions between policymakers. It is important that these discussions are well-moderated and that the policymakers are clearly instructed beforehand on how to interpret the Y-factor and the functionalities of the Y-factor tool. The tool can be used to facilitate discussions on topics like "Where should we apply our policy focus on?" and "What barriers are hardest to overcome in our country and how can we tackle this?". To let these discussions flourish, policymakers can use the tool to change Y-factor values to express their personal beliefs regarding the abatement options.

The third option would be to use the tool for creating representative and reliable Y-factor reference curves. In this case, it is recommended to make the tool available for policymakers, or policy advisers that have familiarised themselves with the Y-factor methodology and have sufficient expertise on the considered abatement options to create a reliable Y-factor curve for the situation at hand. In this way, the strength of the Y-factor as a reference curve for showing implementation complexities can be kept, but with the

addition that it allows for contextual changes that are required to adapt to the situation at hand.

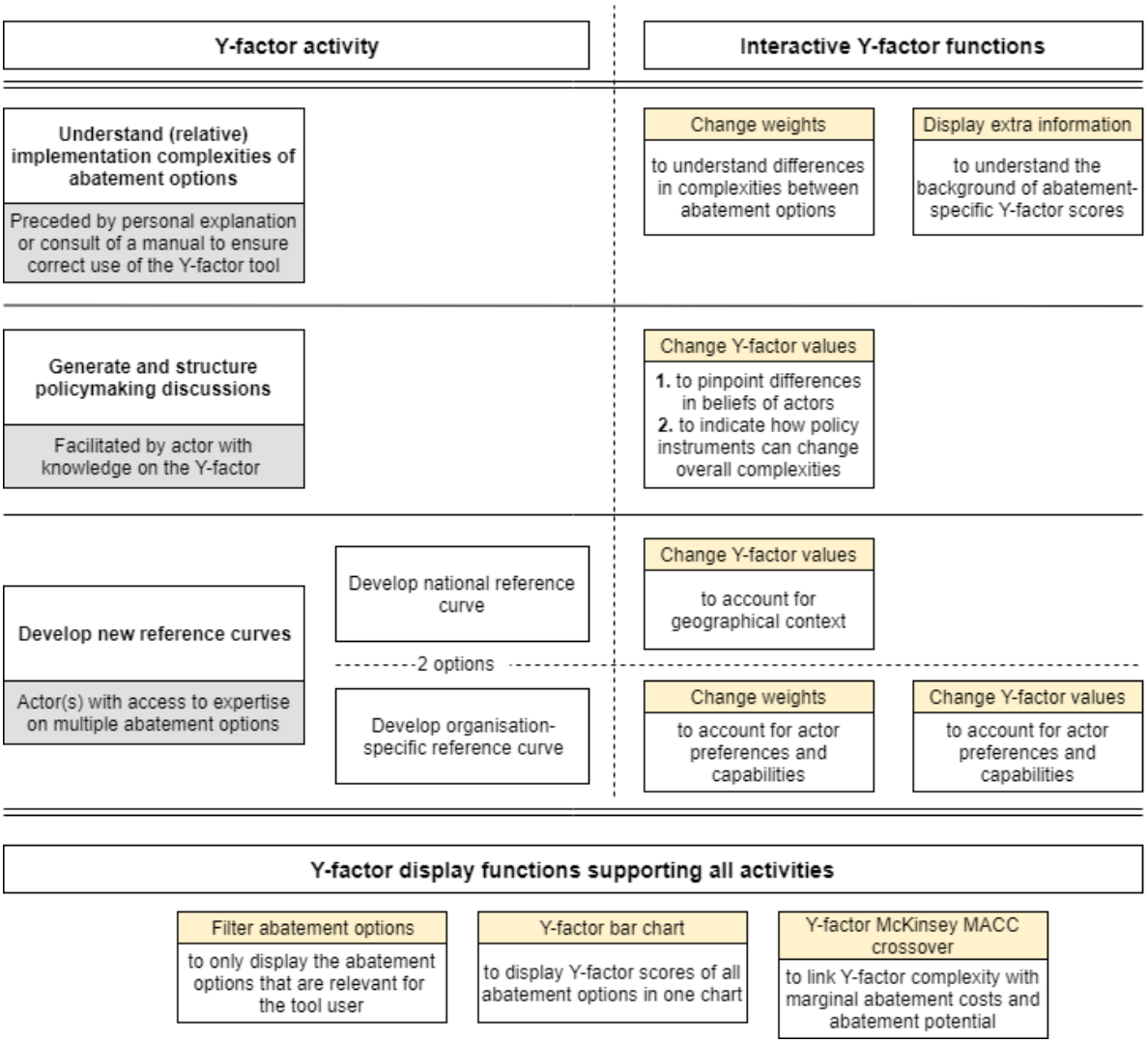

Figure 7.1: Y-factor tool activities

The next paragraphs address the main conclusions of the research. This is done by addressing the answers on all the sub questions in the enumeration below.

1. "In what stages of the policy cycle can the Y-factor be applied?"
2. "How can the Y-factor be made more accessible and facilitated in use for policymakers?"
3. "How can the applicability of the Y-factor tool for carbon abatement policymaking be tested in focus groups?"
4. "How do policymakers value the contribution of the Y-factor (tool) for carbon abatement policymaking?"

7.1.1 Where does the Y-factor fit within the policy cycle?

The policy cycle distinguishes five stages: issue identification, policy formulation, policy decision-making, policy implementation and policy evaluation. An analysis of all different stages and an investigation into how the Y-factor could fit into these stages led to multiple conclusions. The main conclusion is that the Y-factor, which provides a generic set of criteria to help and steer policymakers, would fit most logically within the policy formulation and decision-making stages. The ability of the Y-factor to provide a high-level overview of many different abatement options facilitates policy formulation. This overview helps policymakers to understand the main complexities that need to be considered before policy implementation. Moreover, the Y-factor can be used to conduct a multi-criteria decision analysis in order to compare, rank and prioritise abatement options on a set of criteria which indicate the complexity of implementation. In the phase of policy implementation, the Y-factor is less suitable as this phase requires more specific information than the Y-factor can currently provide. With regards to policy evaluation, the Y-factor has the potential to provide a generic framework to assess policies, but this would only be valuable if a policy instrument was specifically introduced to lower a certain implementation barrier. The conclusion that the Y-factor is most suitable for policy formulation and decision-making led to the recommendation of adding functionalities to the Y-factor support tool, such as the automatic ranking of abatement options and relative factor weights.

7.1.2 How can the Y-factor be made more accessible and facilitated in use for policymakers?

The Y-factor as developed in earlier research was relatively static and did not show all the relevant information underlying the displayed Y-curve. To account for varying implementation complexities in different regional contexts with different policymaker norms, values and opinions, a web-based tool to support policymakers was developed during this research. The tool displays the Y-factor bar chart and includes functionalities to change relative factor weights, change abatement option-specific factor values and provide the possibility to include only information from the abatement options that are relevant for the user. As marginal costs curves are a dominant method to decide on carbon abatement policies, a scatterplot is designed that includes the values of the Y-factor, as well as the McKinsey MACC. The tool interface is designed to be as effective, flexible and easy to use as possible.

7.1.3 How can the applicability of the Y-factor tool for carbon abatement policymaking be tested in focus groups?

To test if and how the Y-factor tool could be used most effectively by policymakers, a focus group methodology was designed. In this context, using focus groups is advantageous because of several reasons. First, it allows for replicating real-world policy discussions. Second, by moderating a discus-

sion that is structured with predefined questions, more information can be obtained in a shorter amount of time. The focus group was centered around three case studies that were chosen to stimulate discussions between the participants. These discussions were preceded by a presentation on the Y-factor and followed by a questionnaire. This research shows a positive appreciation for the focus group methodology. It was observed that discussions on Y-factor generated interaction between the participants and that it enabled conclusion making. It also led to a critical reflection on the tool itself.

7.1.4 How do policymakers value the contribution of the Y-factor (tool) for carbon abatement policymaking?

By conducting two focus group sessions and three semi-structured interviews with public policymakers and policy advisors, the Y-factor tool was assessed by nine people on its usability and its applicability for carbon abatement policymaking. Hypotheses that were formed in earlier chapters on the policy cycle and the tool functionalities were tested and led to a set of conclusions and recommendations. First of all, the tool can be used to construct reference curves that are specific to the situation at hand. This helps to facilitate discussions on what abatement option to invest in, and subsequently on what policy instruments could be used to facilitate the implementation. Altering the values should be done by knowledgeable people with awareness on how to use the Y-factor.
If the tool were to be used by policymakers without the necessary expert background, it should be done with a different objective. In this case, the Y-factor tool could be used by policymakers to familiarise themselves with the complexities that could hamper the implementation of abatement options and to emerge into discussions on how policy instruments could deal with the addressed complexities. A general conclusion from the sessions was that a reference curve could best be scoped on a national level. This is because most policies are formed nationally and because conditions for policymakers are shaped on a national level.
Moreover, the hypothesis that the Y-factor tool would be most suitable in the phase of policy formulation was confirmed by the interviewees. It was argued, that if the Y-factor were to be deployed for ex-post evaluation, an ex-ante assessment would also be required.
Finally, recommendations were made for Y-factor improvements. Some distinctions between the 12 barriers were unclear to the participants and, therefore, require more specification. Also, the inclusion of a 'laws and regulation' factor was suggested. With regards to the tool, minor suggestions for improvement were made, which can be implemented shortly.

7.2 Recommendations for further research

Throughout this research, choices were made regarding what research to pursue and what to leave for further investigation. These recommendations

for further research are structured in four categories: recommendations for ensuring the right use of the Y-factor tool, recommendations for further development of the Y-factor tool, recommendations for further development of the Y-factor method and finally, recommendations for applying the Y-factor in other fields than policymaking.

7.2.1 Recommendations for the optimal use of the Y-factor

- A first possible cause is that the participants had little to no experience with the Y-factor. This potentially makes it difficult to interact with the tool, and to emerge into discussions with the other participants. To conclude from the information displayed by the Y-factor, it is important to know how to interpret the Y-factor results. For future use of the Y-factor it is recommended to provide policymakers with clear instructions on how to interpret the Y-factor. This could either be in the form of a presentation, or a manual.
- It was recurrently addressed that the marginal abatement cost curves were valued highly because it ranks abatement options on a quantitative criterion. The Y-factor tool was created to expose the complexities of greenhouse gas reduction, but not to provide an exact representation of the real world. As participants were used to MACCs, they were more hesitant to interact with the tool by changing Y-factor values or weights, because they mentioned how this would damage the reliability of the Y-factor curve. The approach that was taken during the focus groups, was to let the participants freely use the Y-factor tool and stimulate them by posing real-world policy questions. This did not always generate the envisioned tool interaction or discussions, and it is recommended to be more direct with participants on how to use the tool and interpret the results. This can eventually take the discussion to a higher level. E.g. *"If you would increase the weights of behaviour and decrease the weights of financials, what happens to the ranking of the Y-factor curve and what can you conclude from this"*

Before using the Y-factor tool, the user should be conscious of their own objective for using the tool, and what activity and functions support this objective. Figure 7.1 shows the main activities that can be conducted with the Y-factor and the functions that support these activities.

7.2.2 Recommendations for further development of the tool

With regards to its functionalities, there are currently no major additions that are needed for the Y-factor tool. However, there are certain possibilities to increase the usability of the tool, and possibilities to further investigate features that could potentially strengthen the tool. Recommendations for further tool development are listed below.

- To make the tool more professional and easy to use, it should be redesigned into a dashboard. This would not demand extra coding in

Javascript, but would merely be a different frame in which the functions would be poured to facilitate the user. Appendix A provides an outline of what this dashboard could look like. The advantage of using a dashboard layout compared to the current layout would be that the tool would fit on one screen without the necessity of scrolling. This makes all functions similarly accessible and increases the usability of the tool.

- For future research, it is recommended to compare the Y-factor tool with other tools that facilitate policymakers. The choice for functions supporting the Y-factor tool was mainly based on recommendations from earlier research and literature analyses. It is recommended to conduct a structured benchmark with more established tools, such as the tool that PBL uses or with the Quintel Energy Transition Model.
- As was mentioned before, the Y-factor tool is created to be easy to use and might therefore be interesting for many different users. When finished, there is the question of whom to provide the tool to. It could either be kept within the TU Delft, be made open-source or be spread strategically. In chapter 8, I provide my personal opinion on that matter.

7.2.3 Recommendations for further development of the Y-factor

This research followed the research by Cheung (2018), Arensman (2018) and Soana (2018), and primarily focused on the application of the Y-factor in the policy arena. More research to follow up on this thesis could be conducted in two general directions: either to continue with incorporating more abatement options in the Y-factor method, or further investigating the applicability of the Y-factor for different users than policymakers.

Recommendations for further development of the Y-factor method:
Despite the research being primarily focused on visualising and adapting the Y-factor in a way to make it suitable for policymakers to use, several thoughts and opinions on the Y-factor method itself were obtained along the process of this thesis research too. Below, possible additions for the Y-factor method are listed. These additions were either directly mentioned by interviewees or were deduced from other conclusions of this research.

- **Creating local (national) Y-factor reference curves**: The Y-factor addresses four categories of complexity that could hamper the implementation of carbon abatement options. The complexity that these categories address is strongly related to the policymakers' (geographical) context. From the conclusions of this research, it could be argued that a large part of this complexity can be explained from a national perspective. Using expert knowledge to develop Y-factor reference curves on a national level could be beneficial for improving the reliability of the Y-factor scores. The Y-factor tool would also become more powerful, once the possibility is given to switch between different national reference curves.

- **Adding co-benefits to the Y-factor**: Adding co-benefits to the Y-factor method is a recurrent consideration throughout earlier Y-factor research and was mentioned again during Y-factor interviews conducted for this research. For policymakers, positive spillovers (e.g. in terms of job creation) are an important consideration when formulating policies or investing in a new abatement option. As the Y-factor aims to provide a fully comprehensive overview of the factors to take into account when implementing abatement options, including co-benefits would therefore be an addition to the Y-factor. This could be done by adding an extra score level (from a 3-scale to 4-scale), although this would make the Y-factor less comprehensive as the Y-curve would than not only show 'negative' complexities but would also incorporate a positive factor. Furthermore, co-benefits are often not barrier-specific, but specific per abatement option. With the creation of the Y-factor tool, co-benefits could however be visualised or highlighted in a way that attention is raised with policymakers, without having to change the curve. A thorough analysis on co-benefits per abatement option would however be needed in advance, and is therefore recommended for further research.
- **Clarifying and further specifying factor barriers**: With regards to the distinction and specification of the Y-factor barriers, there were several misunderstandings with the interviewees when introduced to the Y-factor. First, resistance from the local environment is often mentioned as one of the most important factors for policymakers to decide on what options to implement but is not easily retrievable from the Y-factor barriers. To provide the necessary clarity, it is recommended to specifically address that local resistance is part of this barrier.
  Another point of recommendation is to ensure clarification on how to incorporate laws and regulatory barriers into the Y-factor. There are three possible options to do this: 1) To incorporate regulations into one of the existing Y-factor barriers. Soana (2018) suggested containing this within factor B3 (divisions of roles and responsibilities unclear). 2) To add an extra barrier to the Y-factor. When transforming the Multi-Actor Complexity category to Multi-Actor and Institutional Complexity, a fourth factor (B4) could be included, incorporating the complexity that arises from existing laws and regulations. 3) The third option would be to leave the Y-factor barriers as they are, with the notion that it should be clearly addressed that the complexity of laws and regulations are not included in a factor barrier. A reason for this would be that laws and regulations can have an impact on implementation complexity in any of the other barriers. E.g. some laws complicate physical implementation (area development plans), whereas other laws require many different actors to contribute to the implementation of certain abatement options. For the sake of clarity of the factor barriers, it is recommended to either pursue the second option or to leave the barriers unchanged as mentioned in option three.
- **Further validation of current and more abatement options**: For the Y-factor to be widely used and easy to use, more abatement options

from the McKinsey MACC need to be assessed. Where the McKinsey MACC has assessed over 200 GHG abatement options, the Y-factor curve currently only ranks 24 options. Moreover, earlier Y-factor research (Soana, 2018; Arensman, 2018; Cheung, 2018) showed that expert opinions on Y-factor barriers differ. For the Y-factor to construct more reliable reference curves, more expert opinions are necessary.

Recommendations for further research on possible Y-factor applications: This research focuses on how the Y-factor could be applied for policymaking. However, there are more applications possible for the Y-factor, of which two are listed below:

- **Educational purposes**: The Y-factor provides a perspective on how to tackle climate change in an exhaustive and structured manner. The Y-factor, therefore, has the potential to teach students, but also companies and policymakers how to take into account all forms of complexity in a structured way. As climate change is increasingly referred to as a wicked problem, many students, individuals and organisations are left puzzled and unaware of how they can have their contribution to carbon reduction. The Y-factor can be employed for educational purposes in order to show what forms of complexities need to be considered, and to show how the Y-factor can help policymakers to formulate new policy instruments.
- **Business strategies**: The Y-factor has the potential to help businesses with the strategic allocation of their resources. This can be done by highlighting the most promising carbon abatement options or by providing information on how strategic investments can contribute to lowering implementation barriers to facilitate the introduction of new technologies. More research on how the Y-factor could facilitate investors and businesses is recommended and it would also be interesting to see how the support tool could be tweaked to become of value for more business-oriented organisations too.

8 Reflection

This chapter is used to reflect on the choices that were made in this research and on the contribution it has for science and society. It is concluded with a personal reflection on the use of the Y-factor and carbon abatement policymaking in general.

8.1 Critical choices within the research

This research is structured in two main components: The design and development of a Y-factor tool, and the use of focus groups to test the applicability of the Y-factor and its tool for policymakers. During this investigation, several choices were made, which subsequently influenced the outcomes of the research. These choices and their influences are listed below, ordered by the impact that they have had.

- The focus groups had a significant effect on the process and the outcomes of this research. They led to very productive and insightful meetings. However, only two meetings were conducted. The conclusions that were drawn from these focus groups should therefore be regarded as individual results and can not be generalised. These focus groups did provide new and interesting outcomes, and it would therefore definitely be recommended to conduct more focus groups to create a bigger set of opinions, recommendations and data points.

  The multiple-person discussions led to new outcomes for this research. This was accomplished because remarks of one participant forced the other participants to be more critical and come up with new and more input. More insights were generated than would be done in a conventional 1-on-1 interview. The focus groups consisted of a maximum of three people, which in literature is often mentioned as a bare minimum. However, as the participants were not yet familiar with the Y-factor, this relatively small amount of people was beneficial as it allowed for more time to explain on the Y-factor. Furthermore, it eased the burden of moderating the discussion, leading to better-steered discussions.
- Apart from the focus groups, three 1-on-1 interviews were conducted. These semi-structured interviews were helpful to get insights into current policymaking processes, and for discussing the application of the Y-factor in their jobs. However, these interviews did not allow for testing the interaction between policymakers and the tool.

- The tool was constructed to serve as a starting point for discussion in the policymaking process, based on a policy cycle analysis. Several design choices were made especially to support policy formulation. During the focus group, the participants were asked whether they could verify this assumption. For academic validity, it would have been more accurate if policymakers were provided with a tool without a bias towards policy formulation.
- The introduction of the Y-factor to policymakers led to interesting outcomes. A recurrent and fairly unexpected insight was the perceived hesitance of policymakers to play with Y-factor barrier weights or change the values of the barrier scores of abatement options. A reason for this, which was put forward by a focus group participant, was that the tool would then lose its reliability. Reflecting on how the Y-factor is portrayed, it could be argued that by visualising the Y-factor into a bar chart, the sense of certain objectivity of the Y-factor values is given to its users. The main goal of the Y-factor is to present a high-level overview of implementation complexities in a structured, but a qualitative way.

8.2 Scientific contribution

The Marginal Abatement Cost Curve (MACC) that was proposed in 2007 by McKinsey & Company had the purpose to "provide an objective and uniform set of data that can serve as a starting point for corporate leaders, academics, and policymakers when discussing how best to achieve emission reductions" (Naucler & Enkvist, 2009). In 2016, Chappin (2016) developed the Y-factor with the intention "to give policymakers insight in why abatement options may or may not be hard to realize, apart from their abatement costs". Hereafter, research on the most suitable and applicable factors to determine implementation complexity was conducted (Cheung, 2018; Arensman, 2018) and the first "robust and reliable Y-factor abatement curve" was constructed by Soana (2018). With regards to the initial intention of the Y-factor construction, these three researches focused on "why abatement options may or may not be hard to realise". This investigation provides its scientific contribution on the first part of Chappin's intention: "giving policymakers insight".
This research verified that the Y-factor can be a relevant method for policymakers to consider when discussing the implementation of abatement options, whilst using a broader spectrum of factors than their abatement costs.
A scientific contribution was made as to when to apply the Y-factor in the process of policymaking. For the first time, the Y-factor methodology was matched with a theoretical framework on policymaking; the policy cycle. This analysis led to the conclusion that the Y-factor would be most suitable as a starting point for discussion in the stage of policy formulation.
A second scientific contribution was made through the investigation of how to facilitate the application of the Y-factor to support policymakers in the stage of policy formulation. By benchmarking Multi-Criteria-Decision-Making (MCDM) tools, implementing recommendations from the policy

cycle analysis and investigating usability criteria, a support tool for policymakers was developed. This contributed to the Y-factor research, because the tool facilitates the initial objective of the Y-factor development: 'giving policymakers insight'. The academic analysis and benchmark have led to the facilitation of policymakers by providing easier access to Y-factor analyses, and allowing for the adjustment of Y-factor scores to account for contextual differences.
The third major scientific contribution is the crossover chart, which manages to include the key information from the Y-factor and the McKinsey MACC. This contribution was valued highly by the policymakers that were introduced to the Y-factor tool.

8.3 Societal contribution

Policymaking on climate change is a process, which is mainly driven by financial considerations. This can partly be attributed to the presence of marginal abatement cost curves, but also to the lack of a structured approach to take into account other factors determining the potential success of abatement options. This investigation shows that the Y-factor method can serve as a basis to provide this desired structure for policymakers, as long as it is used and interpreted in the right way.
By continuation of previous Y-factor research, this investigation has developed a support tool to aid policymakers with a clear, detailed and structured assessment of 24 different abatement options on 12 criteria. The main benefit of this tool is the provision of a structure to the twelve qualitative criteria that constitute the Y-factor. The Y-factor considers implementation barriers, which do not hold an objective, quantitative value, but are merely scored on an ordinal 3-point scale. Furthermore, the complexity that is addressed by these factors can, to a significantly larger extent than marginal abatement costs, be very context-specific.
To account for this context-specificity, the designed tool allows policymakers to change values according to their beliefs of the context in which they operate. The tool as an addition to the existing Y-factor method provides the possibility to increase the reliability of the Y-factor scores, and moreover facilitates policymakers to more easily use and understand the Y-factor barriers. The combination of these factors constitutes that a large step was taken in order to help policymakers structure and overcome the uncertainty and complexity that sustainable policymaking brings along.

8.4 Personal reflection on the Y-factor

A question that I asked myself many times over the course of this thesis research is: "Should this also be included in the Y-factor?". This question is inherent to the very broad nature of the Y-factor, and was more than once triggered by remarks of people I interviewed or students I was discussing

my topic with. However, most of the times, I realised that the answer to this question was negative. I realised that the broad scope of the Y-factor is not only its strength, but also poses its biggest threat. When considering the Y-factor, I think it is very important to be aware of the most valuable information it can deliver, but equally important to know how the method should not be interpreted and for what applications other methods are more suitable.

In my opinion, the core strength of the Y-factor lies with its ability to combine many abatement options (24 and growing) and assess each of these options using identical criteria covering a large range of implementation complexities. The Y-factor is at its best when using it for a high-level overview. This integral assessment of abatement options to complement the weaknesses of marginal costs curves establishes a very complete overview of factors to consider. The strength of this complementary approach became even clearer to me after having introduced people to the chart that contained information on both the Y-factor and the McKinsey curve. The information it contained was interpreted correctly and very quickly, which subsequently led to interesting and unexpected insights for these users.

Whilst analysing the potential of the Y-factor for policymakers, it also taught me what the Y-factor is not. The Y-factor can help to provide insight into what complexities a policy should aim to address, but it should not be used or considered as a toolbox to design policy instruments. The Y-factor is similar to MAC-curves, considering the ability to provide a comprehensive, high-level overview. A big distinction however, is that the Y-factor is a qualitative method, whereas MACCs have a quantitative basis. The Y-factor, being a qualitative tool, shall not be used to make 1-on-1 comparisons between different abatement options based on the scores. I believe, that the strength of the Y-factor lies in the supporting information underlying the given score, rather than the score itself. It is my conviction that the Y-factor can be a very powerful method for policymakers, provided that it is used in the right way. Preventing misunderstandings can either be overcome by creating a manual on how to use the Y-factor, or by letting Y-factor discussions be facilitated by an experienced user of the Y-factor.

The positive reactions of the interviewees, have convinced me of the potential that the Y-factor has to become a widely used method. As addressed in the chapter 7, the Y-factor is eminently a method, which is most powerful on a national scope and to become widely recognised, I think that the development of reference curves on a national level should have a high priority. Furthermore, if endorsed by renowned TU Delft professors and experts that were already interviewed, I am convinced that the Y-factor can build a strong reputation.

Optimal use of the Y-factor tool

Chapter 6 and 7 showed that the Y-factor tool can be used for three main activities (educating policymakers, facilitating discussions and creating national reference curves). These three activities are inherently very different and it is therefore key that the user of the Y-factor tool is aware of the objective he/she pursues and uses the functions of the tool that support

this objective. As an example, the use of weights can show the relative differences in implementation hurdles between abatement options, but are less suitable for the creation of a reliable abatement curve.
To ensure the correct use of the Y-factor tool it is crucial that its users are well-instructed beforehand. Discussions will be most productive when facilitated by someone with knowledge on the Y-factor, and the Y-factor can educate policymakers best if they know how to interpret the bar chart and crossover graph.
It is my view that for the Y-factor to become a method that can transcend the academic world and be put into use for policymaking, the Y-factor tool should be made available for everyone as an open-source tool. Not necessarily to reach more policymakers, but as a way to encourage experts to contribute to the creation of local Y-factor abatement curves and validate more abatement options and more barrier scores.

Using the Y-factor tool for generating discussions
A remarkable notion that was recurrent in multiple focus groups and interviews, was the wish of policymakers for the Y-curve to be as specific and reliable as possible. When introduced to the web-based tool, some interviewees were hesitant about the idea of changing Y-factor barrier weights. They feared that the Y-factor would no longer be representative and no longer be of value for policymaking if values and weights were altered. Within the focus group, this hesitance restricted the discussion to flourish.
I believe that the main merit of the Y-factor, and specifically the Y-factor tool, is to generate discussions between policymakers. The Y-factor is meant for highlighting the complexities of the implementation of abatement options. If users of the tool see that changing the weight of a certain barrier, which they find very important, changes the Y-curve drastically, an interesting discussion could start. For example: "Geothermal looks very hard to implement, but when raising the relative importance of behavioural aspects, interestingly, it moves down the curve a lot".
Partly, I think there is hesitance with policymakers, because of the Y-factor's absence as a discussion-generating tool with an established reputation. Another reason that the interviewees mentioned the value of a reference curve, instead of a tool 'to play with and generate discussions', could be attributed to the fact that their knowledge of the Y-factor and the abatement options were, in their opinion, insufficient. I think it would be interesting to investigate why and how tools from other organisations have proven to be effective in generating discussions on specific content.

8.5 Personal reflection on carbon abatement policymaking

Analysing the applicability of the Y-factor for policymaking on climate-related issues also taught me about state of the art of decision-making processes. A first observation is that climate-related policies and investment

decisions are very government-driven. As a result of many uncertainties, market mechanisms are not yet determining investments and the private sector is taking a very reactive attitude awaiting for governmental policies. Remarkably, not even all governmental subsidies that were freed for renewable energy projects (SDE+) were claimed in 2019.
Secondly, decisions on investments for carbon abatement options are primarily driven by financial analyses. Subsidies are, for example, purely paid out based on financial profitability. This does not mean that other analyses, such as bottleneck analyses are not conducted, but the majority of decisions are made with financials as the decisive factor.
The observation that most policies and investments are government-driven, partly because of private party uncertainties, and the observation that most decisions are primarily based on financial analyses, pave the way and raise the need for methods like the Y-factor. Financial analyses will probably remain the most decisive factor, but the need for a robust and reliable abatement curve incorporating more factors than marginal costs alone is growing.
Furthermore, I think that abatement curves, whether it is the Y-factor or the MACC, should be used more frequently, because of the wide range of abatement options that are considered. In the current climate change debate, the focus is always very oriented towards the same sectors; energy generation, mobility and increasingly the industry. It is often overlooked how much of an impact could be made in sectors like the agricultural sector. With the approach taken for the Dutch 'klimaatakkoord' using 'klimaattafels', major steps already were taken to move towards a more integral assessment of abatement options. Using abatement curves like the Y-factor and McKinsey MACC could help to take another step in this direction.

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A MANUAL Y-FACTOR TOOL

This appendix describes how the tool has been coded and how programmers can further develop this tool in the future. Table A.1 shows all the files of which the tool is composed of and what its role is in the creation of the Y-factor tool.

Table A.1: JS, CSS and HTML files creating the Y-factor tool

Filename	Function
factor_data.txt	This is the dataset in Tab Separated Values (TSV) format, containing information on every carbon abatement option
index.html	This is the general outline of the webpage, which organises how the webpage is structured. It uses the bootstrap package in order to provide a column structure to the webpage.
charts.js	This Javascript file uses the d3 library to create three graphs. The bar chart in high and low detail, and the bubble chart that combines the Y-factor with the McKinsey MACC.
functions_variables.js	This file uses Javascript coding to create functions that support the index.html file and the chart.js file. Furthermore, it attaches base values of different variables (such as the standard setting of weights)
information.js	This Javascript file portrays information on the three values associated to the factors of the Y-factor
ycurve.css	This CSS file specifies the lay-out

This appendix will provide a description on the first four files as displayed in Table A.1. The information.js file and the ycurve.css file are straightforward and do not require extra information.

A.1 FACTOR_DATA.TXT

This section describes how the dataset is constructed and how new information can be added. Table A.2 shows the components of the dataset. The dataset has 18 columns, that are all needed to generate the Y-factor tool. This means that for every carbon abatement option, a row of 18 cells needs to be added. The dataset is a tab separated values file (TSV). This means that all columns are separated by a tab. This has been done, because CSV (comma separated values) cannot be used, due to the fact that large pieces of text in the dataset contain commas. A TSV file can easily be opened and created (Save as 'Text (Tab Separated)') by Microsoft Excel.

Table A.2: Structure dataset Y-factor tool

technology	Behaviour3	Behaviour2	Behaviour1	Physical3	Physical2	Physical1	MultiActor3	MultiActor2
name of abatment option	0,1 or 2	0,1 or 2	0,1 or 2	0,1 or 2	0,1 or 2	0,1 or 2	0,1 or 2	0,1 or 2

MultiActor1	Costs3	Costs2	Costs1	maccvalues	potential	label	info	barrier
0,1 or 2	0,1 or 2	0,1 or 2	0,1 or 2	marginal costs (€/tCO2eq)	abatement potential (MtCO2eq in 2030)	Numbering: 1- # of technologies	Info on technology	info on implementation barriers

A.2 INDEX.HTML

This section describes the general lay-out of the web page. The code of the HTML page is fairly straightforward, and specified with ID's and class names to provide more understanding. An element to pay attention to is the bootstrap library which provides a column structure to the web page (https://getbootstrap.com/ provides insight in how to use the Bootstrap library)

A.2.1 Bootstrap column structure

Bootstrap has a standard 12-column layout. Currently, the HTML is built up by two vertical columns. The left part contains the graphs and the weights, taking up 9 out of 12 columns (specified in html with 'col-9') and the right column takes up the other 3 columns (col-3), which is occupied by the technology filter. This column is floating, which means that the technologies will always remain on screen.

A.3 CHARTS.JS

This Javascript file contains the code that creates three graphs. The file itself clearly shows when the code of a new chart starts. As these three charts are coded separately from each other, they can be implemented in any HTML file. These HTML files do need to contain a div-element with a specific id that links to the graphs. Apart from the dataset text file, the charts.js file is not dependent on any other of the files.

- 12-factor Y-factor bar chart: is attached to a HTML 'div'-component that has the id 'barchart_factor'. For tooltip information to appear, a 'div'-component with the id 'tooltipholder_fac' must also be in place.
- 4-category Y-factor bar chart: is attached to a HTML 'div'-component that has the id 'barchart_category'. For tooltip information to appear, a 'div'-component with the id 'tooltipholder_cat' must also be in place.
- Y-factor MACC crossover bubble chart: is attached to a HTML 'div'-component that has the id 'scatterplot'.

Currently, the widths and heights are all specified in pixels (see figure A.1). The disadvantage of this, is that it does not change with different screen sizes. In other words, the graphs are not responsive. Making these interactive graphs responsive, will not be easy as all the underlying components have been programmed to fit within this size. A possible option to make it responsive without having to change pixel values, would be to use 'iframes'. The exact application needs to be looked into further.

```
1 //setting the axis and rectangles for bar chart 12-factor scale
2
3 var margin = {top: 50, right: 30, bottom: 240, left: 170},
4     width = 1070 - margin.left - margin.right,
5     height = 450 - margin.top - margin.bottom;
6
```

Figure A.1: Pixel structure graphs

A.4 FUNCTIONS_VARIABLES.JS

This Javascript file contains the most important functions of the policy support tool. It also executes some of the functions that are specified in the charts.js file, so it cannot be executed without being in the same folder as the charts.js file. The list below provides a description on the most important functions.

- **set_checkbox_lines**: This function creates the list of abatement options as shown on the right side of the tool. It retrieves all the specified technologies from the dataset and couples it to a checkbox. Furthermore, it makes all the technologies clickable.
- **clickme**: The main function that is specified in this Javascript file is the 'clickme' function. This function is executed when a technology is clicked upon in the right column. It pops up a menu that is technology specific, with general + barrier information of the technology and dropdown values for each of the 12 factors.
- **get_value_of / get_info_of / get_barrier_of / get_total_of**: These functions all have a similar objective, which is to get information from the most recent set of data points (So, if values have been changed by the user, the latest data points will be obtained). get_value_of retrieves the value of a specific Y-factor barrier (0,1 or 2). get_info_of retrieves the general information of an abatement option, as specified in the dataset. get_barrier_of retrieves the information on barriers hampering the implementation of an abatement option and get_total_of retrieves the total Y-factor score of an abatement option.
- **submitvalues**: This function is triggered when the Submit Values button is clicked in the abatement option specific pop-up menu. When clicked, the new values that have been specified in the dropdown menu are retrieved, the set_value_of function is executed to create a new dataset with the adjusted values and the Y-factor bar chart and crossover chart are reloaded with the new data.
- **set_value_of**: This function is used to change Y-factor barrier scores in a dataset. After a user has changed the values of a certain abatement option, this function adds the new value to the dataset. It is incorporated into the 'submitvalues' function.

A.5 Y-FACTOR TOOL AS A DASHBOARD

For future development of the Y-factor tool, it is advised to improve upon the lay-out of the tool. Currently, the Y-factor is displayed on a webpage with the bar chart on top and the Y-factor MACC crossover below. Figure A.2, A.3 and A.4 show the lay-out of the Y-factor, which is created to be more efficiently and effectively in use. The development of this lay-out can be created with Bootstrap.js and the use of iFrames.

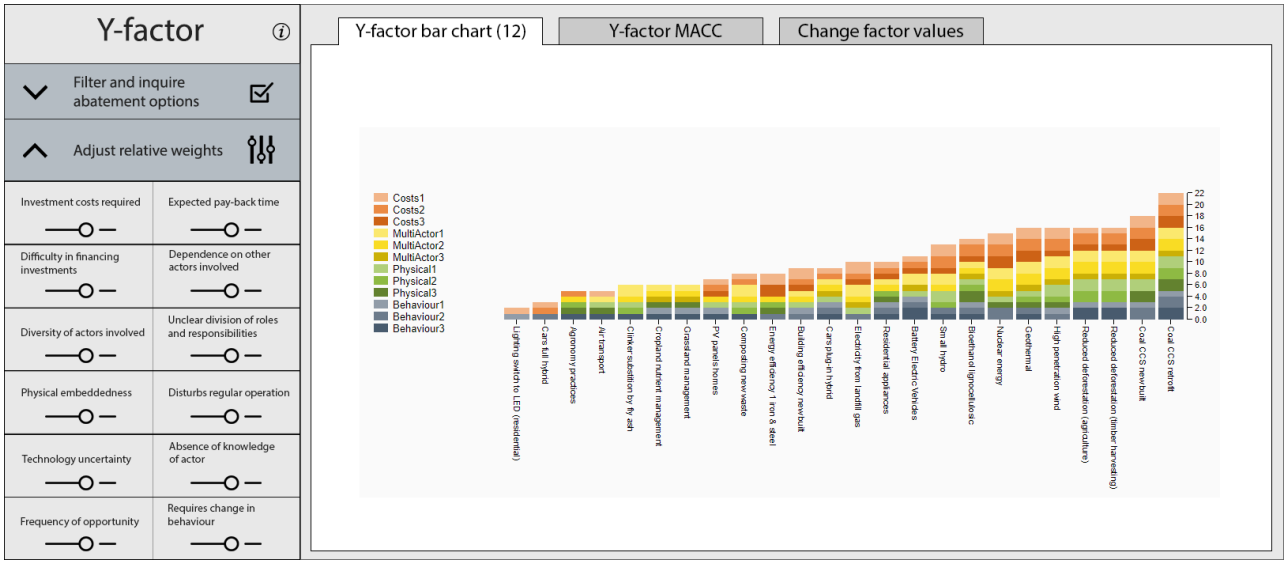

Figure A.2: Y-factor as a dashboard - bar chart

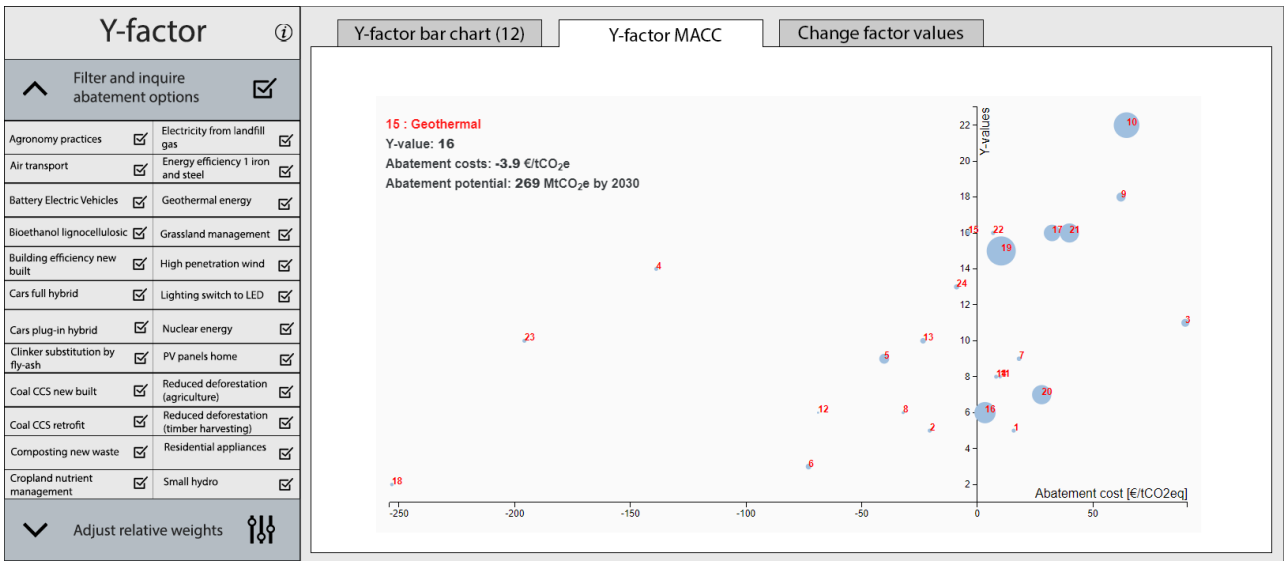

Figure A.3: Y-factor as a dashboard - MACC crossover

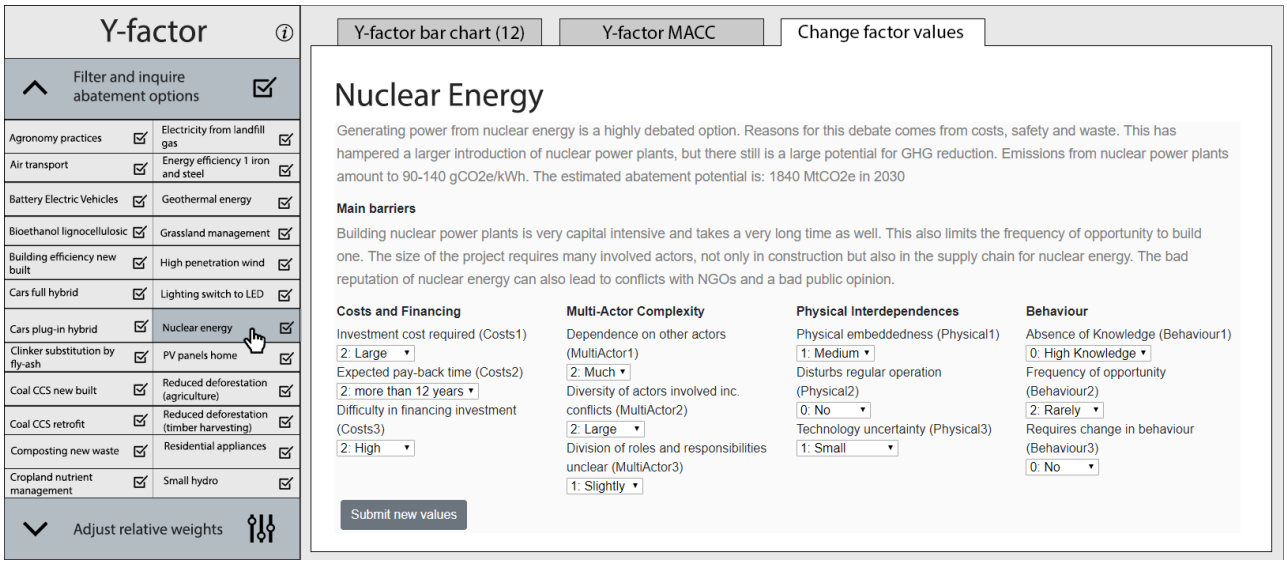

Figure A.4: Y-factor as a dashboard - Change values

B INTERVIEW GUIDE AND QUESTIONNAIRE

This appendix shows the interview guides of the semi-structured interviews (B.1) and the focus groups (B.2). These guides are in Dutch. The outcomes of these interviews and focus groups are discussed in Appendix C and in chapter 6.

B.1 INTERVIEW GUIDE UNSTRUCTURED INTERVIEWS

The next two pages will show the interview guide of the unstructured interviews that I have conducted. These questions have provided structure to the interview, but it must be noted that this interview guide has not been followed 1-on-1.

Interview guide

Datum: 4-6-2019

Openingsvragen:

- Hoe lang werk je bij KWINK?
- Wat zijn de activiteiten waar KWINK zich mee bezig houdt?
- Hoe zou je jouw functie omschrijven?

<presentatie voer de Y-factor>

Vragen waar ik vooral antwoord op wil hebben:

<u>Categorie 1: Advies van KWINK op beleidsvorming en evaluatie</u>

- **Hoe wordt er binnen overheidsinstanties structuur gegeven aan het vormen van klimaatbeleid?**
    - Op basis waarvan worden er keuzes gemaakt voor technologieën / beleidsinstrumenten?
    - Zijn er vaak veel verschillende partijen betrokken?
        - Wat is de invloed daarop op het proces?
    - Wat is de rol van KWINK?
- **Wordt er gebruik gemaakt van vergelijkbare tools zoals deze Y-factor?**

    Ja:

    - Wat doet deze tool?
    - Wat zijn de sterke punten?
    - Wat zijn de zwakkere punten?

    Nee:

    - Waarom niet?
    - Hoe zou het een toevoeging kunnen zijn?

- **Ben je bekend met marginale kosten curves en hoe maken jullie daar gebruik van?**
- **Wat zijn voor jou belangrijke voorwaarden waar een tool aan moet voldoen wil het gebruikt worden?**
- **Wat is de rol van KWINK als adviseur voor beleidsvorming?**
    - Wat zijn belangrijke criteria waar jullie op adviseren?
    - Wat maakt een tool makkelijk in gebruik of makkelijk over te brengen?

<u>Categorie 2: Gebruik van de Y-factor tool</u>

Vergelijking maken van drie verschillende technologieën (naar keuze):

- **Stel er wordt afgewogen op welke van deze drie technologieën er beleid gevoerd zou worden:**
    - Zou op basis van deze tool meer inzicht gegenereerd kunnen worden om beleidskeuzes te faciliteren?
        - Hoe?
        - Wat kan er verbeterd worden?
    - Als je op basis van deze informatie een besluit zou maken, hoe zou je daarmee te werk gaan?
    - Ben je het eens met hoe de technologieën zich tot elkaar verhouden?
        - Waarom (niet)?
    - Zie je het voor je dat de Y-factor zou kunnen helpen om beleidsinstrumenten te genereren?

- **Zouden er aanvullingen gemaakt kunnen worden om deze nog beter in gebruik te laten zijn?**

    - Inhoudelijke toevoegingen om beter in gebruik te maken?
    - Visuele toevoegingen om de functie duidelijker te hebben?
    - Zijn er bepaalde aspecten in de tool nog onduidelijk?
        - Functies aflopen. Duidelijk?

- **Hoe/ waar zou de Y-factor goed gebruikt kunnen worden?**
    - Adviesorgaan?
    - Ministeries?

<u>Categorie 3: Gebruik Y-factor algemeen</u>

- **Hoe zie je voor je dat de Y-factor gebruikt zou kunnen worden bij Kwink?**
    - Situaties die zich voordoen, waarbij de Y-factor goed van pas kan komen?
    - Medewerkers die hier veel gebruik van zouden kunnen maken?
        - Of andere instanties?
    - Gebruiken bij het vormen van beleid? Of juist bij de evaluatie hiervan
    - Gebruiken voor 1 specifieke optie analyseren? Of vergelijken?
- **Kwink maakt gebruik van de beleidscyclus als framework**
    - Wat zijn aspecten die in verschillende fases belangrijk zijn?

B.2 INTERVIEW GUIDE FOCUS GROUPS

The next two pages show the structure of the focus groups as they have been conducted. In practice, the structure of the focus groups was held, but not all questions were asked, as these were mainly formulated to stimulate the discussions if necessary.

Focus Group CE

Presentatie (10 minuten)

Nu kunnen jullie de tool gebruiken (10 min):

- Klik er eens doorheen, stel vragen
- Als jullie dit zien, waarvoor zouden jullie het gebruiken?
- Zijn er dingen die opvallen? Nu onduidelijk zijn?

Focus group discussie (40 min)

Nederland

- De Y-factor heeft meerdere categorieën en die hebben standaard in de Y-factor een even sterke weging. In Nederlands klimaatbeleid, zijn er bepaalde categorieën die sterker mee zouden moeten wegen dan anderen?

Case (Implementatie van 1 technologie)

- Selecteren van 1 technologie. Hieraan zijn bepaalde waardes gekoppeld.
- De waardes doorlopen in tweetallen:
    - Zijn jullie het eens met de waardes?
        - Waarom wel? Waarom niet?
    - Wat zien jullie als het meest complexe bij het implementeren van deze technologie?
- Vergelijken met elkaar?
    - Waar liggen verschillen?
    - Waarom?
- Wat is het meest complexe aan implementatie van de technologie?
    - Kan hier beleid op worden gevoerd om dit te reduceren?
        - Welke instrumenten?
- Wat is de belangrijkste reden om ergens beleid op te voeren?

Case (policy decision making/ advice) -> beleidsinstrument!

- Rechts is een lijst met technologieën en ik zou graag aan de hand van een deel van deze technologieën een discussie voeren over op welke technologie er **beleid (op 1 technologie + instrument)** gevoerd zou moeten worden en hoe. Graag drie verschillende technologieën.
    - **Categorie 1**: Elektriciteit (PV, Wind, Geothermal, (nuclear))
    - **Categorie 2**: Agriculture (Grassland management, agronomy practices, cropland nutrient management)
    - **Categorie 3**: Transport (Air transport, Cars full Hybrid, cars plug-in hybrid)

- *Kijken of de discussie al op gang komt..*
    1. Voordat de tool erbij gepakt wordt: welke optie zien jullie het minste weerstand geven bij de implementatie? Waarom?
    2. Assumptie: de waarden houden zoals deze nu is
    3. Wat zou in dit geval de doorslaggevende factor zijn om voor een bepaalde technologie te kiezen?
        - Speelt de MACC hier een rol in?
    4. Wat zouden jullie adviseren met betrekking tot de technologie waarop er beleid gevoerd zou moeten worden?
        - Hoe zou hier beleid op gevoerd worden?

        - Wat zou je adviseren aan ministerie van Economische Zaken?
        - Zijn er bepaalde aspecten waar beter beleid op te voeren is dan andere aspecten?
    - Kunnen de factoren onderliggend aan de Y-factor helpen bij het bepalen van beleidsinstrumenten?
    - Zo nee, wat ontbreekt er aan?

Case (policy formulation)

- Nu zoomen we uit -> als je nu naar het gehele spectrum kijkt. Zijn er bepaalde opties waar je niet van hebt gehoord en waar je nu van zou denken: hier is meer te behalen dan ik dacht?
    - Creeert dit nieuwe inzichten?
        - Zijn er bepaalde technologieën die beter zijn dan je verwacht?
            - Waarom?
    - Zou dit genoeg informatie geven om serieus naar opties te kijken die voorheen niet meegenomen zouden worden?
    - Waar komt dat door?

Hoe te gebruiken: algemeen?

We hebben gediscussieerd over de waarde 1 technologie, vergelijking tussen 3 technologieën om beleid te voeren, + totaalplaatje. Hoe kan de tool het beste ingezet worden?

- Hoe zouden jullie deze tool inzetten?
- In welke volgorde zou je de tools gebruiken?
    - MACC en dan Y-factor?
- Hoe denk je dat deze methode gebruikt kan worden door beleidsmakers of adviseurs?
    - Wat zijn de belangrijke componenten?
- Wat ontbreekt er om deze tool nog meer geschikt te maken?
    - Wat zouden mogelijke toevoegingen zijn?

Fase in de cyclus

- Zou de Y-factor ook op een andere manier in het beleidsproces kunnen worden gebruikt?
    - Hoe zou je de Y-factor gebruiken als je beleid zou willen evalueren?
    - Beleid heeft niet de uitwerking gehad zoals van tevoren bedacht.

Tool samen 1 keer doorlopen om verbeteringen te doen voor gebruiksgemak

B.3 SURVEY

The questionnaire consists of 3 sections and 30 questions of which the majority can be answered by ranking a 1-5 scale. Filling in the questionnaire takes about 10 minutes. The questionnaire has Dutch questions only, because all participants are Dutch.

B.3.1 Full Questionnaire

Gebruiksgemak (System Usability Scale)

	← zeer mee oneens				zeer mee eens →
Ik denk dat ik de Y-factor graag regelmatig zou willen gebruiken	☐	☐	☐	☐	☐
Ik vond de Y-factor onnodig complex	☐	☐	☐	☐	☐
Ik vond de Y-factor gemakkelijk te gebruiken	☐	☐	☐	☐	☐
Ik denk dat ik ondersteuning nodig heb van een technisch persoon om de Y-factor te kunnen gebruiken	☐	☐	☐	☐	☐
Ik vond dat de verschillende functies van de Y-factor erg goed geïntegreerd zijn	☐	☐	☐	☐	☐
Ik vond dat er te veel tegenstrijdigheden in de Y-factor zaten	☐	☐	☐	☐	☐
Ik kan me voorstellen dat de meeste mensen zeer snel leren om de Y-factor te kunnen gebruiken	☐	☐	☐	☐	☐
Ik vond de Y-factor erg omslachtig in gebruik	☐	☐	☐	☐	☐
Ik moest veel leren voordat ik aan de gang kon gaan met de Y-factor	☐	☐	☐	☐	☐
Bij het maken van een fout kon ik die makkelijk herstellen	☐	☐	☐	☐	☐
De Y-factor ziet er zeer uitnodigend uit om mee te werken	☐	☐	☐	☐	☐

Y-factor en klimaatbeleid

	← helemaal niet				heel erg →
In hoeverre kan de Y-factor nieuwe inzichten bieden voor beleidsmakers? Licht toe	☐	☐	☐	☐	☐
In hoeverre kan de Y-factor helpen bij het genereren van relevante discussies? Licht toe	☐	☐	☐	☐	☐

Hoe kan de Y-factor worden verbeterd om te kunnen bijdragen aan het vormen van klimaatbeleid?

De Beleidscyclus

Volgens het traditionele model van de beleidscyclus doorloopt het proces van beleidsvorming 5 verschillende fases: probleem identificatie, beleidsformulering, besluitvorming rondom beleid, implementatie en evaluatie van beleid. De afbeelding hieronder geeft de activiteiten per fase aan.

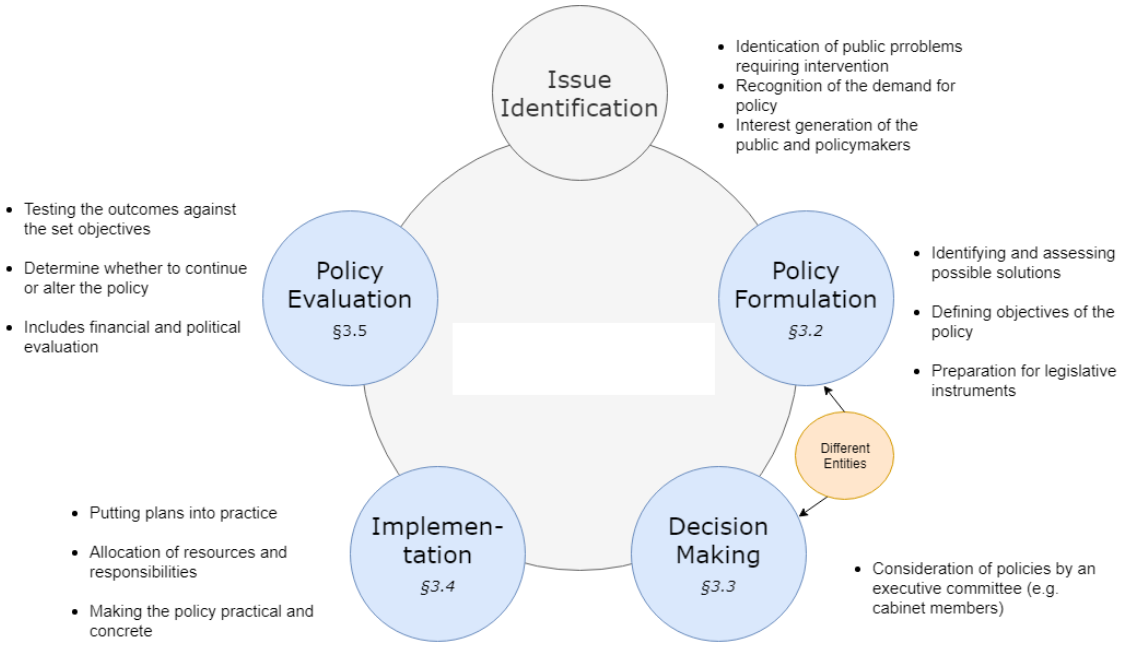

Figure B.1: Phases of the Policy Cycle

In welke fase(s) van de beleidscyclus kan de Y-factor volgens jou het beste worden gebruikt?

Y-factor functies

De tool heeft 6 voornaamste functies: 1) het toekennen van weging aan een factor, 2) het aanpassen van factorwaarden, 3) het filteren van opties, 4) het veranderen van detailniveau,5) het geven van informatie per technologie en 6) de crossover met de McKinsey MACC curve.

Geef hieronder aan hoe nuttig je een bepaalde functie vindt:

zeer nuttig →
← niet nuttig

Toekennen van een weging aan een factor ..... ☐ ☐ ☐ ☐ ☐

Aanpassen van factorwaarden ..... ☐ ☐ ☐ ☐ ☐

Filteren van verschillende technologieën	☐	☐	☐	☐	☐
Veranderen van detailniveau	☐	☐	☐	☐	☐
Geven van informatie per technologie	☐	☐	☐	☐	☐
MACC - YFactor Scatterplot	☐	☐	☐	☐	☐

Geef hieronder aan hoe makkelijk een bepaalde functie is in het gebruik:

	zeer makkeljk → ← zeer moeilijk				
Toekennen van een weging aan een factor	☐	☐	☐	☐	☐
Aanpassen van factorwaarden	☐	☐	☐	☐	☐
Filteren van verschillende technologieën	☐	☐	☐	☐	☐
Veranderen van detailniveau	☐	☐	☐	☐	☐
Geven van informatie per technologie	☐	☐	☐	☐	☐
MACC - YFactor Scatterplot	☐	☐	☐	☐	☐

C ELABORATION OF FOCUS GROUPS AND INTERVIEW

The conclusions are structured on content, rather than on time, and might therefore be extracted from different parts of the focus group. Some of the mentioned points are supported by quotes, recognizable by the quotation marks before and after the sentence. It must be noted that the focus groups were conducted in Dutch, so the highlighted quotes are translated into English.

C.1 FOCUS GROUPS

Two focus groups were conducted, one at the TU Delft and one at CE Delft.

C.1.1 TU Delft

This focus group was conducted at the TU Delft with three master students. One student from the program Sustainable Energy Technology and two students from the Engineering and Policy Analysis master program. All three students have an above average interest for the energy sector, which they express both during and outside of their studies. Compared to the other focus group that is discussed hereafter, this focus group paid relatively more attention to whether the tool was functioning properly and interpreted well. After this focus group, minor adjustments were made to the tool before the other two focus groups were conducted. However, as these changes were so minor, it is highly unlikely they influence the outcomes of the other two groups.

Opinions and possible improvements on the Y-factor and Y-factor tool

Opinions on and suggestions for further development of the Y-factor

- The participants mentioned how a substantial basis of knowledge on different abatement options is required in order to understand and properly use the Y-factor. Partly, because the interpretation of the abatement options depends on the basic understanding of the abatement options: "what is meant by grassland management?". Moreover, they highlighted that it is important that expertise on an abatement option is needed to be able to say something about all twelve barriers determining the Y-factor score.

- Making a clear distinction between the twelve barriers is regarded as difficult by the participants. They tended to interpret some of the factors in the wrong way. They gave the advice to provide more detail in the barrier names, or to give a clear explanation in the Y-factor tool.
- One participant addressed how he would like to show bigger differences between the factor scores and that it might, therefore, be nice to consider changing the 3-point scale into a 5-point scale.
- The Y-factor provided the participants with new and relevant information that they were not aware of beforehand. This can be illustrated by the following observation: "why is there such a difference between different types of sustainable driving? - Ah, when I look at the values and explanation, it makes sense".

Opinions on and suggestions for further development of the Y-factor tool

- The participants mentioned that, even though the bar chart provides insights into the complexity values, it would be a great addition to provide the Y-factor scores in table form too. In this way, the scores might become more comprehensive.
- Currently, the tool is designed in a way that the checkbox list with all abatement options is always on the screen. The participants addressed that this might not be necessary as this list is only used in the beginning when filtering the relevant options.
- The function of the tool to attach weights to Y-factor barriers was interpreted by the participants as to whether it is hard to formulate policies to tackle certain barriers to implementation. With this in mind, the participants thought the weight for costs and finances could be lowered, as financial barriers would be easiest to overcome.
- The participants mentioned that they like the Y-factor MACC crossover and thought that it could be a very useful tool because it contains a lot of information. However, it is feared that, due to its bottom position on the page, it won't be used frequently.
- A possible improvement would be to always be able to show the reference curve as created by Soana (2018), and to be able to compare that one to the one that was created by changing weights and values.
- With changing the weights, a participant mentioned how it is important to have a time scope in mind. Category values might be very dynamic: "currently, local resistance is very active. However, in the long run, it is more likely that some resistance might fade, whereas other complexities might remain or even worsen".

Envisioned applicability of the Y-factor for policymaking

The participants were asked how they would see the Y-factor be used for carbon abatement policymaking, after being introduced to the concept of the policy cycle.

- It was argued that the Y-factor would be most suitable in the early stages of the policy cycle. In the policy formulation and policy decision-making stage, the Y-factor could provide a nice framework to generate a general idea on the associated implementation complexities.
- "If the Y-factor were to be used for policy evaluation, a pre-assessment with the Y-factor needs to be done as well." They mutually agreed that otherwise, the Y-factor would not be suitable for evaluation.
- The participants thought that for policymakers, it is also important to take into account what the societal side effects would be. Knowing the associated co-benefits, such as the creation of new jobs, would constitute an extra reason for choosing a certain abatement option. Also, on the other side of the spectrum: associated disadvantages need to be known beforehand too.
- Apart from policymaking, one participant also mentioned the possible added value of the Y-factor for education purposes. The Y-factor could raise awareness for students, but also for policymakers, on how to judge the applicability and suitability of policy instruments to lower carbon emissions.

Focus group observations

- There was little to no discussion when values of a specific technology were altered. This could be attributed to the fact that the participants thought they were not knowledgeable enough to change the values.
- The discussion was most vivid when comparing different abatement options with each other.
- When asked to compare technologies, the participants felt the urge to change values of abatement options relative to one another.
- A part of the 12 barriers constituting the Y-factor was interpreted in the wrong way. The participants mentioned how they found it hard to distinguish the barriers B2 and B3, B3 and D1, and finally, C3 and D1.
- At first, two of the three participants interpreted the use of weights in the wrong way, as they wanted to change the weights specific for a certain abatement option.

Main takeaway TU Delft focus group

The focus group session at the TU Delft was particularly useful for further improvements on the Y-factor tool. Better specifications and explanations could be given to improve the understanding of both the twelve Y-factor barriers and the carbon abatement options for policymakers that have no or few experiences with the Y-factor or the McKinsey MACC. With regards to the layout and setup of the tool, the focus group mainly had its added value for letting critical people making active use of the tool. The main takeaway

from this perspective is that, although being very relevant, some aspects of the tool were used far less, because of their position on the web page. With regards to its use for policymaking, the hypothesis is confirmed that the Y-factor could be most useful for the policy formulation and policy decision-making stages. Furthermore, the Y-factor could be an interesting tool for evaluation, provided it is used ex-ante as well.

C.1.2 CE Delft

CE Delft is an independent research and advisory agency, specialised at the development of innovative solutions for climate-related issues. This focus group was conducted at the CE Delft office with three of their employees: Martijn Blom, Diederik Jaspers and Reinier van der Veen. See Table C.1

Table C.1: Researchers CE Delft

Martijn Blom	Senior researcher on financial instruments
Reinier van der Veen	Medior researcher on fuels and cities
Diederik Jaspers	Senior researcher on energy saving

The most conclusions were drawn when the participants emerged in a discussion on what phase of the policy process the Y-factor could be of use and on how the Y-factor could be tweaked and improved to be most effective for drafting policies. The next paragraph mentions and structures the most relevant conclusions of the focus group.

Opinions and possible improvements on the Y-factor and Y-factor tool

Opinions on and suggestions for further development of the Y-factor

- The participants would not necessarily advice to change the Y-factor scale from 3 to 5. "It is questionable whether further detailing the scale, would add value and still manage to be specific enough about the complexity."
- For the Y-factor to be suitable for policymakers, the participants mentioned that scores for abatement options need to be validated by more experts. This would make the Y-factor more trustworthy. If more experts would provide their expertise, the participants encouraged to show a confidence interval per factor score, or give the possibility to display the underlying expert information per factor.
- Using the Y-factor as a reference curve would be very interesting when scoped on a national level. "This would be more valuable, than on an international level, because of laws and regulations, which constitute a large part of the implementation complexity, are determined on a national level." Also, weights would then be determined nationally. In

the Netherlands, the participants stated that Costs and Multi-Actor complexity should be given the highest weights.

- The participants were most critical on how the different abatement options are formulated. They were wondering whether the options were scoped by current implementation complexity or estimated complexity until 2030? This issue arose when comparing high penetration wind with PV panels on residential homes. Wind was the far more complex option according to the Y-factor. The main cause of this was the volatility of wind energy production. However, when solar PV would be implemented on a larger scale, this same complexity could arise. Furthermore, it was not clear to the participants whether current policies were incorporated in the Y-factor. As an example, a participant mentioned how costs and financial barriers are currently very low in the Netherlands for PV panels, due to the net metering regulations.

Opinions on and suggestions for further development of the Y-factor tool

- The participants stated that it is important for the tool to be used in the correct manner because otherwise, it could lose its plausibility. The tool should be used by a consultant, knowing the ins and outs of the Y-factor and not by the client to whom advice is given. The consultant can create a reference curve specific to the situation at hand. This is where the Y-factor tool could be at its best: the creation of a new curve that explains the current complexity of a situation. This curve could then be conveyed to the client. If the client starts using the tool by itself, weights and new values might not be used in the appropriate way.
- One of the participants mentioned that the factor weights are not very tangible, but do have a big influence on the Y-factor bar chart results. It creates a sense of reliability, which can't be ensured.
- It was advised to add a reset button for when values have been altered. Just like the reset button for the weights.
- It was recommended to add a possibility to show why and by whom the scores were given. This could, for example, be done by clicking on a technology, that causes a pop-up window to appear with more detailed information.

Envisioned applicability of the Y-factor for policymaking

The participants were asked how they would see the Y-factor to be used for carbon abatement policymaking, after being introduced to the concept of the policy cycle.

- The participants stated how the Y-factor would mainly be suitable for policy formulation and policy decision-making. When it comes to formulation or ex-ante policy evaluation (the term used by CE Delft for formulation), the Y-factor could provide a high-level overview and could be used on the front end, to convey a message on implementation complexities and choices that were made to move away from the reference curve. For decision-making, the participants highlighted that

it could be a nice way to compare different options with one another, especially because the options can be compared using the same factors.

- If the Y-factor tool were to be used for evaluation purposes, the participants mentioned that it should also be used before the implementation of a policy instrument (ex-ante and ex-post). This would then be effective when a policy instrument would be specifically aimed to lower a certain barrier and afterwards be assessed on its effectiveness.
- The Y-factor would be of most use after using the marginal costs curves. The participants envisioned costs to always remain the most decisive factor in determining climate policy. The Y-factor could indeed be strong as complementary to the MACC.
- When asked for possible applications for the Y-factor, a participant mentioned how it could have been very useful during discussions and negotiations of the Dutch 'klimaatakkoord'. For these negotiations, a different dashboard was used, but this lacked an integral way of evaluating options. The Y-factor could provide this in a better way.
- Another possible application for the Y-factor could be to provide more structure to the distribution mechanisms of the SDE+. Currently, only costs are used to determine whom to supply with subsidies.

Focus group observations

During the focus group, the following observations were done:

- The barriers were interpreted wrong: resistance from the local environment was interpreted as a part of the behaviour category, instead of the multi-actor category.
- Initially, changing weights were used to lower the importance of a factor on a specific technology instead of the entire context.
- The discussion was most vivid when different abatement options were compared. No discussion arose when option specific Y-factor values were altered. It was mentioned that this should not be a point of discussion, because they think that the discussions would be more relevant if the Y-factor values would be agreed upon.

Main takeaway CE focus group

The focus group at CE Delft was particularly useful for discussing the applicability of the Y-factor for policymaking. With regards to the policy cycle, the hypothesis was confirmed that the tool would be most useful in the policy formulation and policy decision-making stages. If the Y-factor were to be used for ex-post policy evaluation, it needs to be used ex-ante as well.

Especially for the comparison of different abatement options, the tool is regarded as very interesting, because it provides a framework that can rank the abatement options on the same criteria. The tool could be used for dis-

tribution of SDE+, or as a starting point for broad discussions as conducted for drafting the Dutch 'klimaatakkoord'. With regards to the functions of the tool, the advice is given is to make certain that the tool is used in the correct manner. Changing weights and values are interesting functionalities, provided that they are used properly. When users without the necessary experience make use of the tool, it could suggest a form of reliability that is in fact not present.

The Y-factor could be effective when complementary to the MACC, but the focus group participants did state that costs will always remain the primary consideration for drafting policies. Therefore, the Y-factor can be expected to be used after MAC-curves.

C.2 Interviews

Apart from the focus groups, three semi-structured interviews are conducted: one at the Dutch Ministry of Economic Affairs and Climate, one at the Vereniging van Nederlandse Gemeenten, and another at Kwink Groep. These interviews are conducted in order to gain more insight into the public policy decision making related to climate, and on how the Y-factor could possibly assist this process. Compared to the focus group meetings, the interviews had less focus on the usability of the Y-factor tool. Instead, the interviews were conducted to discuss the applicability of the Y-factor within the policymaking process.

The focus groups, as described in section 6.1, were conducted at companies, with a primary objective to advise governmental bodies. In order to obtain first-hand information on the policy processes that take place within governmental organisations, the interviews were held at two renowned and public organisations that deal with climate policy on a regular basis.

The next sections discuss the outcomes of the three interviews. It must be noted that all interviewees specifically addressed that their comments should be regarded as a personal opinion and should not be seen as an official viewpoint of the organisations to which they are affiliated. The interviewee at Kwink Groep wished to be kept anonymous.

C.2.1 Gerdien van de Vreede - Vereniging van Nederlandse Gemeenten (VNG) - *Data & Monitoring Energy Transition*

Drs. ir. Gerdien van de Vreede, from now on referred to as Van de Vreede, has been working at VNG since 2018 and focuses specifically on facilitating municipalities with the disconnection of neighbourhoods from the gas network. Before, she worked for TKI Urban Energy and CE Delft.

Policymaking within municipalities and at VNG

- Van de Vreede mentioned how at municipalities, but also on a more national level, distribution mechanisms and policymaking are primarily focused on costs and revenues. Different forms of implementation complexities are not neglected but are not taken into account in a structured manner.
- "The complexity of implementing options differs enormously per municipality". This might not be the case for every abatement option, but for getting neighbourhoods off the gas, there are large differences in knowledge and in willingness to adapt.
- Municipalities have been given an important role for the implementation of the Klimaatakkoord, as they are expected to be in the driver's seat for the transition from gas.
- With regards to policy on the energy transition, municipalities work together within the RES (short for Regionale Energiestrategie). By means of collaboration, different municipalities work together in 'regions' to draft policies around four themes:
    1. Electricity and the built environment
    2. Industry
    3. Mobility
    4. Agriculture

These themes are also present in the Y-factor. According to Van de Vreede, the Y-factor could have added value for drafting regional strategies.

Applicability of the Y-factor for public policymaking

- Van de Vreede, shared her expectation of the Y-factor to be very suitable for structuring and generating discussions on why and how to implement certain abatement options. Furthermore, she confirmed that the Y-factor addresses the most important complexities.
- When asked for specifics in the Netherlands compared to other countries, she thought that the Netherlands is specifically restricted in terms of physical embeddedness and that the weight for this category should be higher.
- Van de Vreede expected the tool to be usable, provided that it should be used by the right person in the right way. With changing values and weights, the tool suggests certain objectivity that is in fact not present. She thinks that it could best be avoided to have uneasy discussions on whether the value should be 0,1 or 2.
- What van de Vreede did not like about the Y-factor is that the scores were given based on qualitative interpretation, consequently given an absolute score, to be used for qualitative measures afterwards. This too gives the idea of certain reliability that is not present.

- Van de Vreede especially valued the MACC crossover, due to the high information density in the graph, remaining easy to understand. In her opinion, the three most crucial aspects to consider when drafting climate policies are present in this bubble chart.

Recommendations for Y-factor improvement

- Van de Vreede mentioned that she thinks that a 3-point scale does not allow for enough variation. She recommends using a 5-partite scale or be able to mention that a certain factor has such a high complexity, that it could be given a 'knock-out' value.
- Van de Vreede expected the Y-factor to be of most use for consultancy organisations, as they prefer working with visualizations and graphs. Within public organisations, often textual explanations are preferred.
- She recommended the creation of a manual on how (not) to use the Y-factor. The Y-factor can be used wrongly, as the interpretation of weights for example. With a manual or better explanations within the tool, this could possibly be prevented.
- Laws and regulations are very country-, or even municipality-, specific, and have a high impact on the scores of the Y-factor. Van de Vreede recommended to try and incorporate this into Y-factor barriers.

C.2.2 Lisa van Woerden - Ministerie van Economische Zaken en Klimaat - *Policy Officer Electricity*

Ir. Lisa van Woerden, from now on referred to as Van Woerden, has been working at the Ministry of Economic Affairs since 2017 and currently works as a policy officer for the electricity department. Her main area of expertise lies with coal factories. She is a graduate from the faculty of Technology, Policy and Management at the TU Delft.

Policymaking at the Ministry of Economic Affairs

- Costs are very central in the approach of the Ministry of Economic affairs towards the formation of public policy. SDE+ subsidies for renewable energy are distributed based on marginal costs. Van Woerden mentioned that this is also because the government can be held accountable by its electorate. Financials are in this case the most important to take into account.
- When considering the new technologies, an assessment and analysis of the problem are always performed. Aspects that are taken into account are involved actors, possible instruments, causation analysis of the problem, implications for companies, civilians and others. The structure of the analysis differs per situation.

- Political aspects are very important when it comes to decision making. Van Woerden mentioned how this might be something that could also be considered for inclusion the Y-factor. From experience, she says how permits are often hampering the implementation of new technologies.
- Van Woerden mentioned that when evaluating policy instruments, this is always done on effectiveness and efficiency (*Dutch: doelmatigheid en doeltreffendheid*).

Applicability of the Y-factor for public policymaking

- Van Woerden shared her expectations that the Y-factor might be useful within the department of climate at the Ministry. The broader climate goals are formulated here. Furthermore, in the case of the climate goals of Urgenda, the Y-factor could be used to determine what options need to be implemented quickly in order to make sure enough achievements are made before 2020.
- Van Woerden especially liked the MACC crossover and easily managed to draw conclusions from it. She likes how three valuable pieces of information are contained within one graph for 24 different options.
- Specifically for the Netherlands, van Woerden envisioned that physical interdependences would be the hardest category to take into account when drafting policies. She stated how behaviour and costs are also hard, but that these can more easily change, whereas the Netherlands will remain physically limited.

Recommendations for Y-factor improvement

- Van Woerden advised incorporating laws and regulations into the Y-factor as this can really hamper implementation.
- Van Woerden mentioned how many policy officers do not always know how to interpret these graphs containing a lot of information. At the Ministry, policy offers are used to texts instead of visualizations. She would, therefore, recommend constructing a manual.

C.2.3 Kwink Groep - *Consultant*

The interviewee has been a consultant for Kwink Groep since September 2018 and primarily works on topics of climate and energy policy, which is one of the four main topics in which Kwink Groep operates. 95% of Kwink Groep clients are from the public sector (on a local, provincial and national level).

Climate policy at Kwink groep

- The interviewee mentioned how Kwink uses a slightly altered version of the policy cycle to structure the process of climate policy into four stages: plan development, plan execution, monitoring of progress and the final phase considers learning & justifying.
- For many people and organisations, climate change and the formulation of climate policy is very complex. The interviewee mentioned that she is convinced that climate policy should always be tangible and formulated SMART, in order for governmental agencies to have a clear set of actions[1]. By doing so, monitoring and evaluation are also facilitated.
- Within the phase of policy formulation, Kwink makes use of the 'Theory of Change' concept. When formulating a policy, objectives are generated and subsequently, certain conditions have to be met to fulfil these objectives. These conditions are distinguished into four categories: technology, business case, public acceptance and laws + regulations. To meet these conditions, policy instruments are linked to the mentioned conditions.

Applicability of the Y-factor for public policymaking

- The interviewee mentioned how, by structuring complexity into categories, the Y-factor could possibly help to overcome a difference of opinions that policymakers hold.
- Using the Y-factor and especially changing factor values or weights requires time and expert knowledge. Therefore, she would not envision the Y-factor to be used on a local level, but either to be used by consultants/ research institutes or on a more national level.
- Her first thought on the Y-factor applicability was that it could have added value as a monitoring instrument. A baseline could be created on the complexity of implementing a certain technology and this could be monitored throughout the execution of a policy using the Y-factor.
- When changing values of the different Y-factor barriers and weights, the reliability of the tool might fade. The interviewee envisioned that the Y-factor might therefore be more relevant as a reference curve, provided that concrete actions could be linked to the barriers.

Recommendations for Y-factor improvement

- When starting up the tool, a lot of information and many technologies are shown. The tool might become more tangible and clearer if only a few technologies show in the beginning, and an option is provided to show all technologies at once.

1 Specific, Measurable, Achievable, Realistic and Time-bound

- The interviewee mentioned how she found it hard to place two complexities into a Y-factor category: public acceptance and laws + regulations. She would recommend to either formulate some Y-factor categories more clearly or consider adding an extra barrier.
- Even though she realized it might be hard, the interviewee mentioned that it would help to think of a policy instrument toolbox that could link to certain Y-factor categories, and in this way facilitate policymakers.

C.2.4 Main takeaway interviews

For the semi-structured interviews, a different approach was taken compared to the focus groups. More findings were obtained on the policymaking and policy advising processes within the VNG, Kwink Groep and the Ministry. Worth mentioning is that all interviewees mentioned how laws and regulations on a national level can highly impact the Y-factor scores. This gives rise to the idea of either clearly incorporating this into one of the twelve existing barriers or scoping the entire Y-factor on a more national level.

Furthermore, the interviewees value MAC-curves, because in the public sector most decisions are made based on financial evaluations. The combination of the Y-factor with the MACC was therefore appreciated. With regards to the applicability of the Y-factor, van Woerden mentioned that it can be of a great benefit at the Ministry to structure and visualize implementation complexities. Van de Vreede is a bit more sceptical due to the qualitative nature of the Y-factor and the small range of the Y-factor values (of 0,1 and 2).

Another recurrent topic during the interviews is the comprehensiveness of the Y-factor. The interviewees mentioned that the Y-factor contains a lot of information, but also requires a great deal of knowledge to make use of the method. In order to ensure that the Y-factor (tool) is used in the correct manner, users need to be informed well on how to use it.

D INFORMATION OF ABATEMENT OPTIONS ON WEBSITE

This appendix shows the information that is contained within the Y-factor support tool. Per abatement option - the Y-factor score, the marginal costs and the abatement potential is shown. Furthermore, a general elaboration and the main barriers to implementation are presented. Figure D.1 shows how this information is presented in the web-tool.

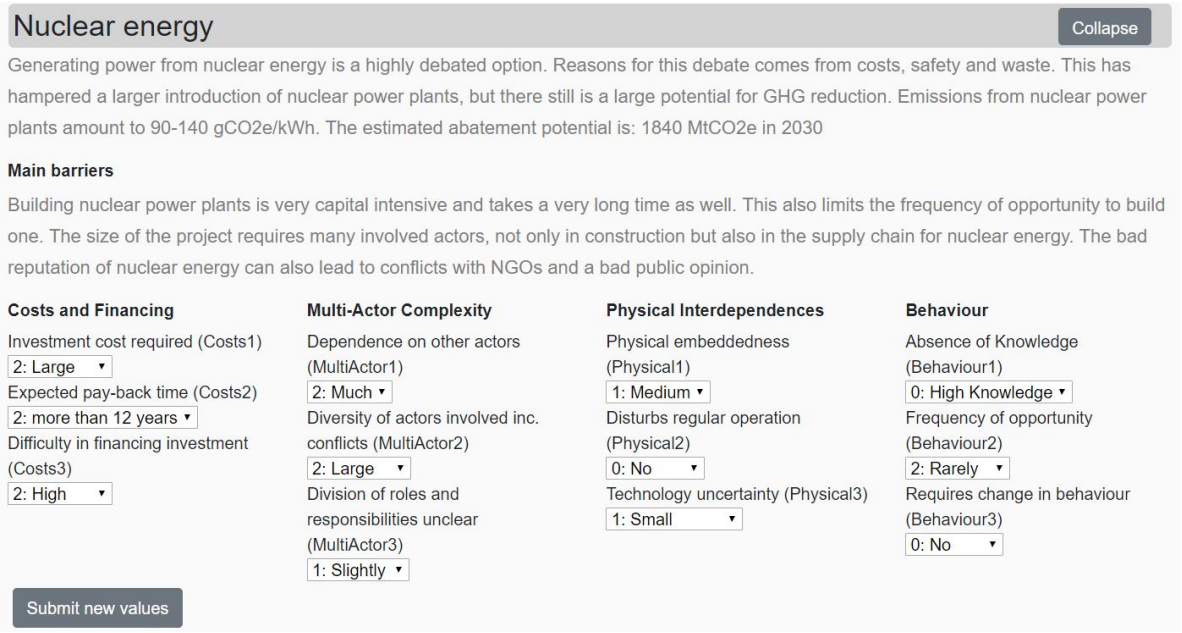

Figure D.1: Information Abatement options

ABATEMENT OPTIONS AND CORRESPONDING INFORMATION

Abatement option: Agronomy practices
Total Y-factor score: 5
Marginal costs: 15.8 €/tCO2eq
Carbon abatement potential: 255
General information: This abatement option improving agriculture mechanisms, using less intensive cropping system, new seeding methods and managing the rotation of crops. This could lead to better sustainability of the soil and an estimated emission reduction of 0.2 tCO2e/hectare per year.
Main barriers to implementation: The main challenge of changing agronomy practices lies with farmers not being used to new seeds and methods.

This may lead to different pay-back times, disturbed regular production and a demanded change in behavior.

Abatement option: Air transport
Total Y-factor score: 5
Marginal costs: -20.5 €/tCO2eq
Carbon abatement potential: 256 MtCO2e in 2030
General information: This abatement option focuses on different processes within the air transport sector in three categories: the operations-efficiency improvements, using alternative fuels and improving infrastructure and air-traffic management. T
Main barriers to implementation: Changing fuel for air transport requires higher production costs and might imply a change in suppliers, hampering the implementation. Furthermore, some physical changes might be necessary in the alternatives fuels infrastructure. For improving operational efficiency, the main challenge lies in renewed cooperation between actors as air traffic control, airports etc.

Abatement option: Battery Electric Vehicles
Total Y-factor score: 11
Marginal costs: 90 €/tCO2eq
Carbon abatement potential: 500 MtCO2e in 2030
General information: This abatement option considers full electric vehicles using chemical energy to store electricity in rechargeable battery backs. This option is expected to have a great emission-reduction potential, but market introduction still is relatively slow. A reduction of about 3.2 tCO2e/year could be accomplished compared to using conventional gasoline ICE vehicles.
Main barriers to implementation: Main barriers to implementation of the electric vehicles are associated to the costs and uncertainty of the infrastructure, the range of the car and the higher upfront investments that are needed. The most complexity arises from the infrastructural perspective as this is still very minimal. This requires a change in behavior and new collaborations between the different actors.

Abatement option: Bioethanol lignocellulosic
Total Y-factor score: 14
Marginal costs: -138.8 €/tCO2eq
Carbon abatement potential: 248 MtCO2e in 2030
General information: This abatement option considers the second generation biofuel bioethanol lignocellulosic. This is produced from sources such as agricultural residues, forest residues, woody energy crops and feedstock. The CO2 reduction potential can reach up to 90 percent.
Main barriers to implementation: The technology is not yet proven on a large scale, which leads to high uncertainties. It could therefore still make efficiency improvements that could lead to better pay-back times as these are currently very high. Furthermore, coordination amongst actors is required in terms of production, but also when it comes to using new biofuels as not all motors are able to cope with the second generation biofuels

Abatement option: Building efficiency new built
Total Y-factor score: 9
Marginal costs: -40.2 €/tCO2eq
Carbon abatement potential: 624 MtCO2e in 2030
General information: This abatement option considers the improvement of energy efficiency levels for newly built housing. The demand of energy consumption can be improved through improved building design related to better insulation, better use of materials and higher efficiency water heating. Leadership in Energy and Environmental Design (LEED) is one of the leading programs and can lead to a GHG reduction of 16%.
Main barriers to implementation: Investment costs for buildings with higher efficiency are approximately 8% higher than for conventional buildings. This is relatively quickly paid back. On a physical level, changes are fairly minor and the knowledge on technologies is often present. As multiple parties will be involved with the construction of new buildings, possible conflicts might arise and there is mutual dependence. Furthermore, the frequency of opportunity is fairly limited as buildings cannot be built anytime, anyplace.

Abatement option: Cars full hybrid
Total Y-factor score: 3
Marginal costs: -72.9 €/tCO2eq
Carbon abatement potential: 359 MtCO2e in 2030
General information: This abatement option considers the transition to more vehicles with both an ICE and electric motor onboard. It is calibrated to run on the electric motor or ICE motor depending on the conditions. Roll-out of full hybrid cars could lead to a reduction 2.7 tCO2e/year compared to using conventional ICE vehicles.
Main barriers to implementation: The main barriers to implementation lie in the category of costs and financing. Full hybrid cars are slightly more expensive than conventional cars with an internal combustion engine. Apart from this, a car is only bought once every 5-10 years, limiting the frequency of opportunity.

Abatement option: Cars plug-in hybrid
Total Y-factor score: 9
Marginal costs: 18.1 €/tCO2eq
Carbon abatement potential: 282 MtCO2e in 2030
General information: The introduction and further development of plug-in hybrid vehicles, i.e. full-hybrids that can be recharged both by the vehicle-driving cycle and by external sources, enabling the vehicle to run more frequently on electrical power. An emission reduction of 2.7 tCO2e/year compared to the gasoline ICE vehicles can be achieved.
Main barriers to implementation: Requires an upfront investment, although it is not much higher compared to conventional ICE vehicles. High barriers are present in the need for a charging infrastructure. This has its impact on a multi-actor level as many different parties are involved and dependent on each other. Furthermore, it has an impact on the physical

environment. The presence of range anxiety for plug-in vehicles leads to a required change in behavior, although this is less as is the case for Battery Electric Vehicles.

Abatement option: Clinker substition by fly ash
Total Y-factor score: 6
Marginal costs: -32 €/tCO2eq
Carbon abatement potential: 189 MtCO2e in 2030
General information: Reducing the clinker content in cement, by substituting clinker with industrial components such as fly ash. This can reduce process and combustion emissions as well as power needed for clinker production.
Main barriers to implementation: The main implementation barriers lie in the dependence on other actors that need to supply fly ash to cement producers. Furthermore, new technologies and transport systems hamper easy implementation of this carbon abatement option.

Abatement option: Coal CCS new built
Total Y-factor score: 18
Marginal costs: 62.2 €/tCO2eq
Carbon abatement potential: 572 MtCO2e in 2030
General information: This abatement option considers the carbon capture and storage in newly built coal power plants. As the design of new built plans can be made from scratch, it has more potential for efficient capture of carbon emissions. The total emission saving from capture and avoidance amounts to 1.5 -1.8 tCO2/MWh.
Main barriers to implementation: High upfront investments are required with long pay-back times. Furthermore, conflicts might arise for storage of the captured carbon and many actors are involved in both the supply chain as in the debate (environmental agencies). On a physical level, the physical impact on transport and storage is considerate and there is still uncertainty concerning the effectiveness on a high level. A final barrier is the frequency of opportunity for the construction of a new CCS power plant.

Abatement option: Coal CCS retrofit
Total Y-factor score: 22
Marginal costs: 64.6 €/tCO2eq
Carbon abatement potential: 1620 MtCO2e in 2030
General information: This abatement option considers the carbon capture in existing coal power plants by capturing the CO2 from the point source of exhaust gases. Storing will consecutively be stored in deep geological formations.
Main barriers to implementation: High upfront investments are required with long pay-back times. Furthermore, conflicts might arise for storage of the captured carbon and many actors are involved in both the supply chain as in the debate (environmental agencies). On a physical level, the physical impact on transport and storage is considerate and there is still uncertainty concerning the effectiveness on a high level. Furthermore, the installation requires at least a year. A final barrier is the frequency of opportunity for

the construction of a new CCS power plant.

Abatement option: Composting new waste
Total Y-factor score: 8
Marginal costs: 9.9 €/tCO2eq
Carbon abatement potential: 221 MtCO2e in 2030
General information: Recycling and composting reduce the introduction of new waste to landfills. This avoids methane emissions from new organic waste. Composting, or aerobic digestion is s a biological process with compost as final product that can be used for further applications. The emission reduction of composting new waste is about 1 tCO2e/ton per ton of waste, compared to waste emitted originating from a landfill.
Main barriers to implementation: Composting new waste requires investments for new machinery. This is however a fairly small investment. The main barriers to implementation arise from the need of support from municipalities to have a recycling system and a place to sell compost in place. This could possibly lead to conflicts and also require a change in behavior.

Abatement option: Cropland nutrient management
Total Y-factor score: 6
Marginal costs: -68.8 €/tCO2eq
Carbon abatement potential: 132 MtCO2e in 2030
General information: Improved nutrient management reducing GHG emissions, by reducing fertilizer-waste, increasing land efficiency and implementing rotational land practices. An estimated reduction of 0.14tCO2e/hectare per year is estimated. A 5-20% reduction would mean a reduction of 56 -224 MtCO2.
Main barriers to implementation: The barriers related to costs and financing are very low. The main barriers are present in the categories of multi-actor complexity and behavior. Improving the nutrient management requires a change in behavior for farmers and also involve a dependence on other actors because new products are needed. Furthermore, it might have an impact on quality of the end-product that could lead to conflicts.

Abatement option: Electricity from landfill gas
Total Y-factor score: 10
Marginal costs: -23.4 €/tCO2eq
Carbon abatement potential: 351 MtCO2e in 2030
General information: This abatement option considers the capturing of landfill gases to generate electricity. The landfill gas is composed mainly out of methane (CH_4) and carbon dioxide (CO_2). 75% of the landfill can be captured over its lifetime. Direct use of landfill gas is highly net-profit-positive, because of the savings from using it as a fuel for nearby industrial facilities.
Main barriers to implementation: The technology is fairly expensive due to the costs of the pipes to recover the gas. Multi-actor complexities might arise as the power plant operator and the owner of the landfill site are often different actors and might not always agree. On a physical level and

behavioral level, the implementation barriers are minimal.

Abatement option: Energy efficiency 1 iron & steel
Total Y-factor score: 8
Marginal costs: 8.2 €/tCO2eq
Carbon abatement potential: 246 MtCO2e in 2030
General information: Improving energy efficiency in the iron and steel industry by structural production shifts, improved process flows, innovations on pumping systems, coal moisture control, or heat recovery. Especially, recovering energy from waste heat from the blast furnace could improve the efficiency.
Main barriers to implementation: This carbon abatement option requires a large upfront investment, but can relatively quickly be paid back. Furthermore, improving energy efficiency has its physical impact as processes are complex and need to run 24 hours per day. Also new efficiency technologies are relatively less certain than conventional methods.

Abatement option: Geothermal
Total Y-factor score: 16
Marginal costs: -3.9 €/tCO2eq
Carbon abatement potential: 269 MtCO2e in 2030
General information: This option considers large scale geothermal energy generation. Deep drilling is necessary to generate electricity from geothermal heat. The most widely used technology for generating geothermal energy is the employment of a geothermal fluid passing through a heat exchanger heating another fluid with a low boiling point, which in turn vaporizes and drives a turbine. The emissions of geothermal energy amount to 50 gCO2e/kWh.
Main barriers to implementation: The main barriers originate from the categories of costs and financials and multi-actor complexity. Drilling machinery is very expensive and the power generation is too. On a multi-actor level, barriers mainly originate from social conflicts (earthquakes, soil quality) ad the many hustles with munipiality that often prevent private investments in geothermal projects.

Abatement option: Grassland management
Total Y-factor score: 6
Marginal costs: 3.4 €/tCO2eq
Carbon abatement potential: 1343 MtCO2e in 2030
General information: Focuses on increased grazing intensity, irrigation of grasslands, fire management and introduction of new species. Central in this approach, les the elimination of any pesticide or fertilizer. The consequence of this approach is that roots go deeper, water-retention increases, plants are more pest-resistant and soil fertility improves. This could lead to an estimated reduction of approximately 0.23 tCO2e/hectare per year.
Main barriers to implementation: In terms of costs and physical interdependencies there are no significant barriers hampering the implementation of improved grassland management. The main challenges lie in collab-

oration with multiple farmers that work within the same consortia, or farmers that share the same land. This could potentially lead to unclear responsibilities and conflicts. Furthermore, a change in behavior is required for the farmers.

Abatement option: High penetration wind
Total Y-factor score: 16
Marginal costs: 32.4 €/tCO2eq
Carbon abatement potential: 1043 MtCO2e in 2030
General information: This option considers wind energy, with a penetration of the energy mix higher than 10%. This distinction between low and high penetration is made because a high penetration level requires more adaption of the network to account for the variability coming from wind energy. This means that the costs per MWh move from â,¬2-3 to â,¬3-5 per MWh.
Main barriers to implementation: High investment costs are required with fairly high payback times. On a multi-actor level, there are many actors that are dependent on each other for activities as construction, connection to the grid and communication with the local environment. The latter could lead to conflicts between actors. The physical implication on the environment is high and has a high impact on others. It could also disturb regular operations by means of the volatility of the wind energy that needs to be fed into the grid. The impact on a behavioral level is fairly limited.

Abatement option: Lighting switch to LED (residential)
Total Y-factor score: 2
Marginal costs: -253.1 €/tCO2eq
Carbon abatement potential: 221 MtCO2e in 2030
General information: This abatement option considers switching incandescent lighting to LED lighting in residential homes. LED lights are estimated to be 40% more efficient than fluorescent lights and even 80% more efficient than common incandescent lights.
Main barriers to implementation: For consumers to switch to LED lighting, there are very few significant barriers to implementation. The current investment costs of a LED are approximately â,¬10. Furthermore, not all consumers are yet fully aware of the advantages that LED bring and are still less known than the most popular incandescent light bulbs.

Abatement option: Nuclear energy
Total Y-factor score: 15
Marginal costs: 10.4 €/tCO2eq
Carbon abatement potential: 1840 MtCO2e in 2030
General information: Generating power from nuclear energy is a highly debated option. Reasons for this debate comes from costs, safety and waste. This has hampered a larger introduction of nuclear power plants, but there still is a large potential for GHG reduction. Emissions from nuclear power plants amount to 90-140 gCO2e/kWh.
Main barriers to implementation: Building nuclear power plants is very capital intensive and takes a very long time as well. This also limits the

frequency of opportunity to build one. The size of the project requires many involved actors, not only in construction but also in the supply chain for nuclear energy. The bad reputation of nuclear energy can also lead to conflicts with NGOs and a bad public opinion.

Abatement option: PV panels homes
Total Y-factor score: 7
Marginal costs: 27.9 €/tCO2eq
Carbon abatement potential: 1216 MtCO2e in 2030
General information: Installing solar energy on the homes of individual house owners. Producing solar energy has no emissions. Construction of the panels accounts for 20-80 gCO2e/kWh.
Main barriers to implementation: Installing PV panels requires a significant upfront investment that have a pay-back time of about 7 years. Physical implementation might in some cases be hard due to differences in rooftops and position towards the sun. Furthermore, a required change in behavior might be present with the rise of smart grids.

Abatement option: Reduced deforestation (agriculture)
Total Y-factor score: 16
Marginal costs: 39.9 €/tCO2eq
Carbon abatement potential: 1208 MtCO2e in 2030
General information: This abatement option considers the decrease of deforestation for agricultural use by compensating landholders from the lost revenue from one-time timber extraction. 70% of deforestation comes from agricultural use and this leads to biodiversity losses, soil erosion and CO_2 emissions.
Main barriers to implementation: The costs mainly originate from annual payments to protect areas from being run-over. This investment does however not have a return on investment. Multi-actor complexity arises from the distribution and generation of the finances. Furthermore, preventing an event to happen is harder than implanting new practices. The ultimate goal of this carbon abatement option leads to a high physical embeddedness. On a behavioral level, local people need to find new occupations as their main source of income changes.

Abatement option: Reduced deforestation (timber harvesting)
Total Y-factor score: 16
Marginal costs: 6.9 €/tCO2eq
Carbon abatement potential: 262 MtCO2e in 2030
General information: This abatement option considers reduction of emissions from deforestation due to unsustainable timber extraction through compensation to landholders for lost timber revenue.
Main barriers to implementation: The costs mainly originate from annual payments to protect areas from being run-over. This investment does however not have a return on investment. Multi-actor complexity arises from the distribution and generation of the finances. Furthermore, preventing an event to happen is harder than implanting new practices. The ultimate goal of this carbon abatement option leads to a high physical embeddedness. On

a behavioral level, timber companies need to embrace sustainable forestry instead of the 'cut it and leave it' business model.

Abatement option: Residential appliances
Total Y-factor score: 10
Marginal costs: -195.8 €/tCO2eq
Carbon abatement potential: 255 MtCO2e in 2030
General information: This abatement option considers the improvement of efficiency within residential homes by replacing appliances, such as refrigerators, washers, dishwashers and air conditioning with higher efficiency models. This also involves the smart usage of these appliances, by using sensors to analyze the right moment to use energy.
Main barriers to implementation: The barriers to implementation for improving efficiency of residential appliances are spread over all four Y-factor categories. There are upfront investments needed that are often slightly more expensive than for conventional appliances. The multi-actor complexity mainly arises when smart networks become more upcoming, as this requires new dynamics in collaboration. On a physical level, smart grids also provide uncertainties. Behavioral changes originate from having to use new equipment in a different way on different times.

Abatement option: Small hydro
Total Y-factor score: 13
Marginal costs: -8.9 €/tCO2eq
Carbon abatement potential: 329 MtCO2e in 2030
General information: This abatement option considers the small scale generation of hydropower of an installed capacity around 25-50 MW. There is high potential for this abatement option as only 25% of the potential has been developed. This small scale hydropower is mainly generated by obtaining energy from river flow.
Main barriers to implementation: The main implementation barrier is the necessity for available upfront financials. The pay-back time approximates 20 years. As the projects are very large, the amount of actors involved is large and their dependence on each other is high. On a physical level, the impact on the physical environment is present. Especially when it comes to introducing dam-projects.

E | SCIENTIFIC ARTICLE

See next pages

Facilitating the process of carbon abatement policymaking by exposing the complexities of GHG reduction

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[a]*Submitted in partial fulfillment of the requirements for the degree of Master of Science in Complex Systems Engineering and Management*

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Y-factor
Climate strategy

ABSTRACT

Binding climate agreements and the necessity to lower greenhouse gas emission levels requires increasing implementation of carbon abatement options and supporting policies on a global level. Due to the wide range of possible strategies, policymakers experience problems in choosing the right carbon abatement strategy. This challenge has led to the creation of the Y-factor, which provides a high-level overview of the complexities to deal with when implementing abatement options. However, the Y-Factor has not yet reached the stage of development to be ready for an introduction into the policy arena. It has not yet established a reputation, and is still relatively underdeveloped in comparison with alternatives and has no proven functionality in real-world situations. By applying the theoretical framework of the policy cycle, conducting focus group sessions and interviews with policymakers, this research has tested the applicability of the Y-factor for policymaking. This led to the conclusion that the Y-factor method could very well assist policymakers in the phase of policy formulation by highlighting the most important implementation barriers and facilitating discussions on how to tackle these. To increase its reliability and subsequently improve its usability for policymakers, it is advised to create carbon abatement reference curves on a national level.

1. Introduction

In October 2018, the International Panel on Climate Change (IPCC) released a report with scenarios revealing the urgency of tackling climate change at a faster pace in order to avoid irreversible damage. An increase of more than 1.5 degrees Celsius would mean that the Earth's atmosphere would become unstable, that CO2-levels would become uncontrollable, and consequently, temperatures would rise even further [10]. As human beings have been the cause of this change in climate, for many the dust has finally settled that human beings should also be the ones to fight and reverse the processes that are heating up the earth. The assembly of national representatives during COP21 led up to the Paris Agreement. An agreement that has provided every country with binding goals for the emission of GHG reduction [18].

The responsibility for the development of plans and policies to reach the COP21 goals lies with the national governments. In the Netherlands, this led to the development of a national climate agreement. Formulating and executing the necessary policies presents a large challenge for many countries, because the number of carbon abatement options to choose from is very extensive and the exact outcomes of these options remain relatively unknown. A method that has been widely used amongst researchers and policymakers in order to facilitate the choice for the right abatement options is the marginal abatement cost curve (MACC). This curve shows carbon abatement options in a bar graph and ranks them on their marginal abatement costs (€/ ton CO2), whilst showing their carbon abatement potential for 2030. From the marginal cost curves that currently exist, the MACC from McKinsey is leading in academic literature [14].

This economic way to analyze abatement options has been leading in literature, public and private sector but is also increasingly contested. It is claimed that abatement options should not only be ranked on marginal costs but that the associated benefits need to be taken into account too [19]. Furthermore, an argument against the suitability of MAC-curves for prioritising, is that complexity in behavioural aspects, technological issues and uncertainties are overlooked by only taking into account marginal costs [11]. The latter arguments have been the main driver for Chappin to construct a new method, which incorporates all forms complexities that might hamper the implementation of abatement options, the Y-factor [4].

The Y-factor addresses a wide range of complexities that determine why an abatement option may or may not be hard to realise. Apart from financial factors hampering the implementation of carbon abatement option, the Y-factor includes three more categories; multi-actor complexity, physical interdependences and behavioural complexities. These categories are further specified in twelve socio-technical barriers (three per category), which collectively determine the Y-factor score for a carbon abatement technology. Each of the factors is scored on a tripartite scale. Either a 0, 1 or 2 can be attributed to these factors. The meaning of the scores differs per factor, as a majority of the criteria has a qualitative nature. With twelve factors to be scored with either a 0,1 or 2, the score that an abatement option could get ranges from 0 to 24, with 0 being 'easy to implement 'and 24 being 'nearly impossible to implement'. Figure 1 shows the 12 different Y-factor barriers.

Since the first introduction of the Y-factor in 2016, Arensman [3] refined the Y-factor method by comparing Y-factor barriers with barriers that were mentioned throughout IPCC reports. This led to a refinement of the Y-factor categories and the removal of a 13th Y-factor barrier, which used to be included. Cheung [5] conducted a similar research approach as Arensman, but linked the Y-factor to the theoreti-

Category	Factor	Value 0	Value 1	Value 2	Definition
(A) Costs and Financing	Investment cost required (A1)	Absent	Medium	Large	Degree to which the investment in an abatement measure is significant
	Expected pay-back time (A2)	<5 Years	5-12 years	>12 years	Expected time required to earn back the investment for an abatement measure
	Difficulty in financing investment (A3)	Low	Medium	High	The degree to which it is difficult to finance the abatement or attract appropriate financial means
(B) Multi-actor Complexity	Dependence on other actors (B1)	No	Little	Much	Degree of dependence on actions of other actors to successfully implement and execute the abatement measure
	Diversity of actors involved inc. conflicts (B2)	Low	Medium	Large	Degree of diversity of interests, values, roles, skills and expectations of the actors involved. Degree of public acceptance. When opposing interests from the (local) public to the implementation or the abatement option are (expected to be) present, a high score should be given.
	Division of roles and responsibilities unclear (B3)	Clear	Slightly	Unclear	The extent to which the roles and responsibilities for the realization of the abatement option are clear
(C) Physical Interdependences	Physical embededdness (C1)	No	Medium	High	Degree to which the abatement measure requires physical changes to the environment it is placed in
	Disturbs regular operation (C2)	No	Slightly	Strongly	Degree (duration, intensity) to which status quo/regular operation is disrupted to successfully apply the abatement measure
	Technology uncertainty (C3)	Fully proven	Small	Large	Degree to which the technological performance of the abatement measure is uncertain
(D) Behavior	Absence of knowledge of actor (D1)	High Knowledge	Low Knowledge	No Knowledge	Level of knowledge of the parties responsible for the abatement measure
	Frequency of opportunity (D2)	Often	Medium	Rarely	Number of opportunities for the responsible party to realize the abatement measure
	Requires change in behavior (D3)	No	Slight	Severe	Degree to which the actors involved need to change their day to day behavior

Figure 1: The Y-factor methodology

cal concept of the transition theory. More recently, research on the Y-factor method was conducted by Soana [16], who constructed the first reliable Y-factor abatement curve, by analyzing and scoring 24 different abatement options.

Hereafter, expert interviews were conducted, which confirmed that the curve was valid and insightful. Interestingly, with regards to the envisioned applications of the Y-factor, opinions differed strongly across the interviewed energy strategists. The Y-factor's possible applications ranged across three activities: to support policymaking, research analyses or business strategies.

This article, based on the thesis report by Swart [17], focuses on how the Y-factor could be employed for policymaking. It constitutes the first research on the possible applicability of the Y-factor. The McKinsey MACC was once developed with the purpose to 'serve as a starting point for policymakers when discussing how to best achieve emission reductions'. In turn, this article investigates how the Y-factor coulf be applied for policymaking. This is done using the following research question: "*How can the Y-factor best be employed for public policymaking?*"

To support this research question, the policy cycle is used as a theoretical framework. The policy cycle characterizes the policymaking process as an iterative process consisting of five different stages. This framework is used to support the research question in order to identify in phase(s) of policymaking the Y-factor can be applied. This will be discussed in section 2. The conclusions from this analysis have been tested in focus groups, which will be discussed in section 3, followed by conclusions and recommendations in section 5.

2. Theoretical Framework

The policymaking process is a complicated process, which has for decades been debated and been explained by different theories and frameworks. Common approaches, among many others, that help understanding the policy process are the Advocacy Coalition Framework, the Multiple Streams model and the policy cycle. All of these approaches have a certain analytical value and specific focus. However, they have also been subject to substantive criticism.

Of all the theories used to define policymaking processes, the policy cycle is one of the oldest, but still very often used in academic literature. The framework was first introduced by Lasswell in 1951 [12] and separates the policy process into different stages. Contrary to other widely used approaches, the policy cycle is a far more simplified representation of the policy process. The policy cycle breaks down policymaking into five different stages. These stages help to describe the process going from problem identification till evaluation of the policy. The simplicity of this representation of the policy process has led to it both being utilised and criticised a lot. [13].

The policy cycle approaches the policymaking process from a high level perspective, making it possible to analyse nearly every policy process. The wide applicability of the Y-factor, and its current lack of practical experience in the policy arena are the main motives to use the policy cycle

as a framework to test the applicability of the Y-factor for policymaking.

Within this research, the policy cycle was used as having five different stages: problem identification, policy formulation, policy decision-making, policy implementation and policy, which is the most widely used approach [9]. Some scholars identify extra stages in between the existing stages, such as a monitoring stage before evaluation, or a termination stage after evaluation, but these stages are not considered as a separate stage in this research. Four of the five considered stages will be described below and the possible application of the Y-factor within these stages will be discussed. The phase of issue identification is not addressed, as the Y-factor assumes an already defined issue.

Policy formulation

The policy formulation stage follows the issue identification stage in the policy cycle. Within this stage, policy objectives are specified and multiple policies are formulated to solve the identified issues and meet the set objectives. The main objective of the policy formulation stage is to provide decision-makers with multiple policy alternatives to tackle the issue that has been identified in the first stage.

There are several activities that characterize the process of developing policy alternatives. Dunn [7] distinguishes three categories of activities. This categorization of activities is used to determine if and where the Y-factor could be applied within this stage.

- **Forecasting through the use of scenarios** will be primarily conducted in situations where there are high (scientific) uncertainties: The Y-factor does contain two barriers that could raise the need for a scenario analysis: information on technological uncertainty and unclear responsibilities of actors. However, the Y-factor itself does not contain any information to conduct scenario forecasts itself.

- **Identifying and recommending policy options** can be done by different analyses, such as a cost-benefit analysis, a cost-effectiveness analysis or a multi-criteria analysis: The Y-factor could potentially be used as a tool to conduct these analyses, as it considers multiple criteria and has the capability to address the critical complexities of the possible policy options.

- **Problem structuring or framing** is conducted by using methods such as brainstorming, boundary analyses and argumentation mapping to provide a solid background for argumentation: The Y-factor is a method that ranks abatement options on different qualitative criteria, which are inherently context-dependent [16]. The Y-factor could subsequently be useful to generate and structure discussions between policymakers.

Decision-making

The phase of policy decision-making follows after the formulation phase. Possible policies are drafted during formulation, and consecutively executive policymakers make a final decision on which policy to implement during the stage of decision-making. The decision-making stage shows similarities with the stage of policy formulation as, in both stages, policies are assessed on a set of criteria. However, small distinctions are present. Within policy formulation, policies are designed and developed based on criteria, whereas the stage of decision-making is more about choosing a final policy mix, rather than developing new policies.

There are three main types of analyses that could be executed during the stage of decision-making [15]: a Life-Cycle Analysis, a Cost-Benefit Analysis and a Multi-Criteria Decision Analysis (MCDA). As the Y-factor makes use of multiple criteria to generate new insights, but hardly contains aspects that are needed for a Life-Cycle Analysis or the necessary detail of a Cost-Benefit analysis, the Y-factor is most suitable as a method to conduct a multi-criteria decision analysis. There are multiple possible applications for when to use MCDA [6, 1], which are in line with possible applications of the Y-factor. These are listed below.

- **Choice**: The Y-factor has the potential to select one alternative from a given set of alternatives, by using the twelve different Y-factor barriers.

- **Ranking and prioritizing**: Two similar selection methods, which can be conducted using the Y-factor in order to determine what abatement options might be easier to implement than others. As the Y-factor considers qualitative factors, the comparison and ranking of options must be done with careful consideration.

- **Conflict resolution**: this considers the settling of disputes between parties with incompatible objectives. The Y-factor has the potential to play a role in structuring discussions and highlighting why objectives of different policymakers do not align.

For the Y-factor to be more suitable within this stage, some additions are recommended. An important component for decision-making is the access to information showing the impact that considered abatement options could make. By combining Y-factor scores with the abatement potential and marginal costs of the McKinsey MACC, this could be effectuated. Furthermore, an investigation into the co-benefits of the different abatement options is recommended.

Policy Implementation

The implementation stage of the policy cycle follows after decision-making and precedes the evaluation stage. It constitutes the translation of a plan into practice, as the formulated policies from earlier stages are executed[13]. A main characteristic of this stage is that it serves to concretize and further specify all plans that have been made till that moment. It, therefore, has a higher level of detail than its prior stages. There are three core elements that characterize the stage of policy implementation [8]:

- **Specification of program details**: Implementation of a policy demands for an action plan. It must be

clear how laws and regulations must be interpreted and which agencies are responsible for executing the program.

- **Allocation of resources**: The distribution of budgets, personnel and responsibilities.
- **Decisions**: This implies the necessity of a structure on how decisions shall be carried out for individual cases. The effectiveness of the implementation stage depends on how well bureaucracies execute the orders [13].

The stage of policy implementation has a prominent focus on concretizing the outlines of the formulated policy and putting this into action. As the Y-factor indicates complexities for the implementation of abatement options, it can address where policymakers need to pay specific attention to. However, regarding the high-detailed nature of the implementation stage, application of the Y-factor is illogical. To improve the applicability of the Y-factor in this stage, information should be added on what policy instruments (regulatory, financial, informational or organizational) could help to overcome high implementation barriers of an abatement option. The development of this extra function would however not align logically with the current application of the Y-factor, which is meant to provide a high-level overview of complexities.

Policy evaluation

The aim of policy evaluation is to find out whether and to what extent a policy has accomplished its goals or whether it has had other intended or unintended effects. Furthermore, underlying reasons and causalities that have contributed to these outcomes are investigated in order to determine which parts of the policy need to be adjusted for higher effectiveness of the policy. The three different possible outcomes of the policy evaluation stage are : 1) the policy is successful and will be continued, 2) the policy does not fully return its intentions and is modified to be more successful, and 3) the policy is terminated [2]. There are multiple reasons for terminating a policy, varying from a lack of impact, a lack of finances, or a full achievement of the policy goals.

As mentioned in earlier sections of this chapter, the Y-factor can prove its worth by providing a multi-factor approach to the development of policy on carbon abatement related topics. This multi-factor approach can assist the evaluation of policy in a similar way. The Y-factor can be especially helpful for determining the causes of either a successful or failing policy. If a policy has not fulfilled its objectives, this could be related to a wrongly specified focus of the deployed of instruments. However, it is questionable if the application of the Y-factor as a general framework will be effective for policy evaluation, as the necessary level of detail in an evaluation might be to high for the Y-factor to fit in. Furthermore, application of the Y-factor might not be useful if it has not been used for ex-ante evaluation too.

Conclusion

The primary focus of application for the Y-factor will be on the formulation of the policy and the consecutive decision-making. The main argument for this choice is that the requirements for these phases lie closest to the inherent nature of the Y-factor. The formulation phase and decision-making phase benefit from an analysis that helps to compare different policy options on multiple factors. The Y-factor could support this process, due to its twelve criteria that spread across the most important themes hampering the implementation of certain policies. The Y-factor is less suitable for the implementation stage as this stage requires a higher level of detail in the decisions that are made. Even though it might prove more useful than in the implementation stage, the Y-factor also has a weaker match with the evaluation stage s because the main strength of the Y-factor lies in combining multiple criteria to come to a decision regarding the formulation of a policy, rather than looking back at what criteria should have been applied beforehand. Figure 2 gives an overview of the possible applications of the Y-factor for policymaking and shows this in a graphical representation of the policy cycle.

3. Testing the Y-factor's applicability for policymaking

The literature review on the policy cycle concludes that the Y-factor fits best within the early stages of the policymaking process: the stage of policy formulation and decision-making. In order to support the application of the Y-factor as a method for multi-criteria decision making, and to provide insights into the complexity of abatement options, a web-based tool was developed. This tool gives policymakers the ability to get insights into the information underlying Y-factor scores, change the relative importance of the 12 different Y-factor barriers, and was provided with a scatterplot graph, which functions as a crossover between the Y-factor and the MACC. The graph shows the carbon abatement potential, the marginal costs and the Y-factor score.

This tool was used to present the Y-factor to participants of focus groups. Focus groups, which were used to test the applicability of the Y-factor for policymaking, and to test the conclusions drawn from the policy cycle analyses. The focus group methodology can be typified as a qualitative research method, which is conducted with a group of at least three people. Within a focus group, the goal is to generate discussions on predefined questions or case material. The argumentation behind the choice for using focus groups, is twofold. First of all, focus groups discussions generate more insights in a shorter amount of time than one-on-one interviews would do. Moreover, the generated discussions, if moderated well, can lead to different insights because the participants trigger new ideas with each other. Not only content can be registered, but observations can also be made on the Y-factor's ability to support group discussions. Secondly, with the predefined questions and case materials, the focus group methodology naturally provides the possibility

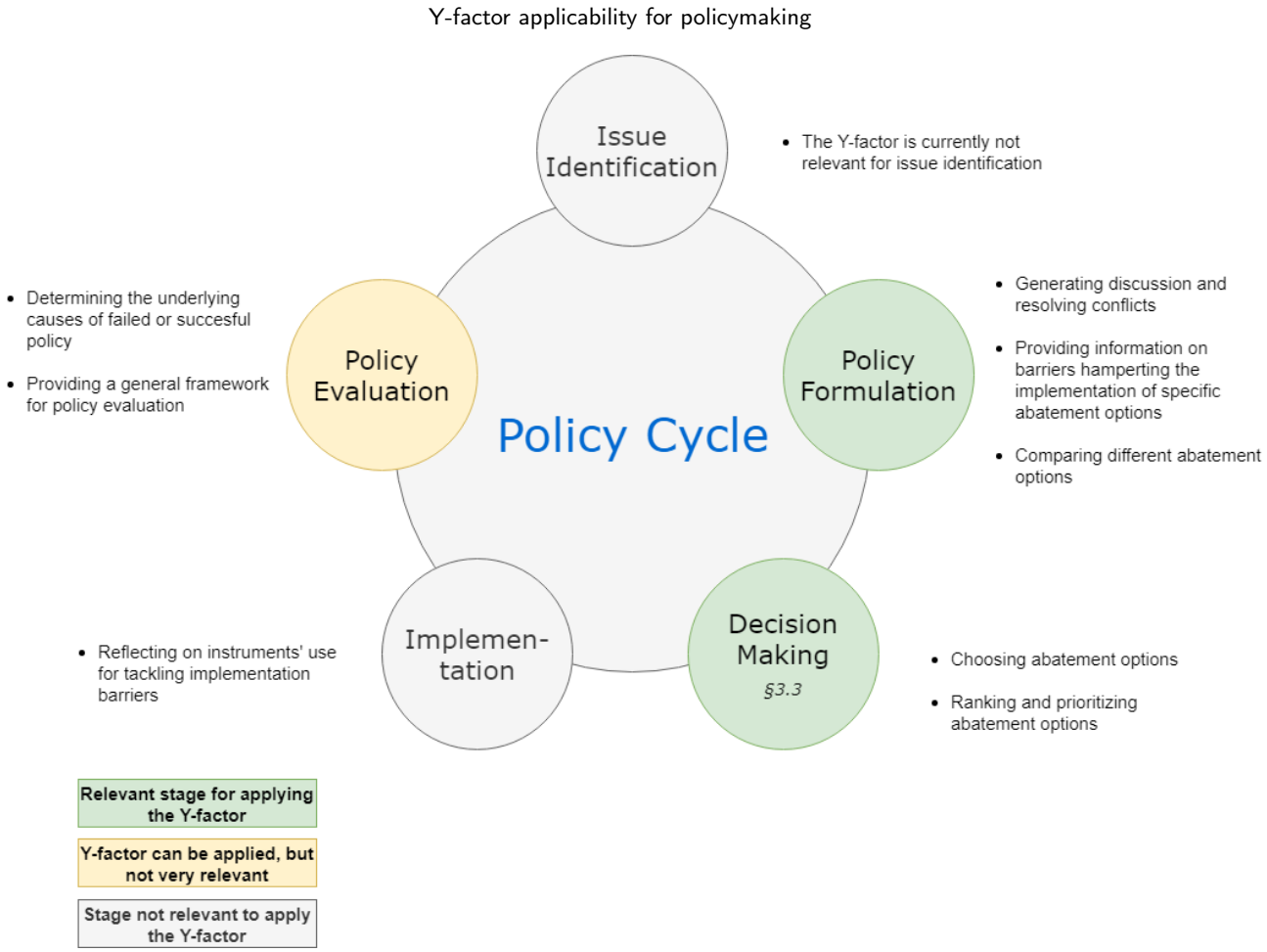

Figure 2: Phases of the Policy Cycle

to recreate real-world situations within discussions.

In total, two focus groups were conducted. One focus group was held at the Delft University of Technology with three MSc students from the faculty of Technology, Policy and Management. The other focus group was held at CE Delft, which is a research institute that delivers advice on climate related issues to public organisations. Both focus groups had three participants, and had a duration of 90 minutes. The discussions were preceded with a presentation, which described the background of the Y-factor research. All participants were given access to the web-based Y-factor tool.

Apart from the two focus group sessions, three 1-on-1 semi-structured interviews were conducted at public policymaking organisations in the Netherlands. These were conducted to generate more insights into current policymaking processes concerning the choice of carbon abatement options.

4. Results

In this section, the findings are described according to the important themes that were derived from the focus groups and interviews.

Applicability of the Y-factor for policymaking

During each of the focus group sessions and interviews, participants were asked how they would envision the Y-factor to be most suitable within the policymaking process. Many recognized the ability of the Y-factor to provide a high-level overview of many different abatement options. This overview would help policymakers to get insights into the main complexities that need to be considered before implementing new policies. Participants mentioned that, because the Y-factor is quite generic, it would be most useful in an early stage of the policymaking process. Figure 3 shows the results of the questionnaire that was filled in by the focus group participants. When asked for the possible application of the Y-factor for policy evaluation, several participants addressed that this would be possible, but would not be in line with the core strength. Moreover, a participant mentioned *"If the Y-factor were to be used for policy evaluation, it would have to be used ex-ante as well, in order to see if progress was made"*.

When asked how they would foresee the Y-factor to be used for policy formulation, the participants shared expertise from their own experiences. They addressed how most decisions for policymaking are made based on financial criteria. At CE Delft, marginal cost curves are very popular. They did however recognize the need for an integral way to assess

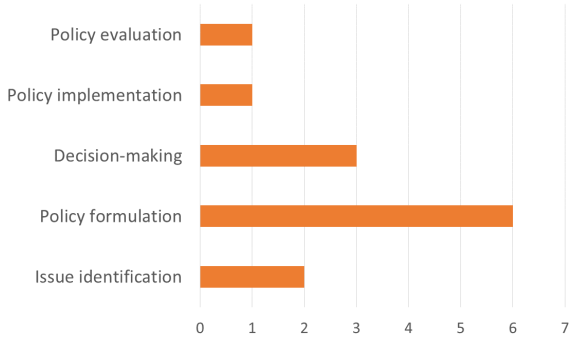

Figure 3: Y-factor in policy cycle

policy options on other than financial criteria and envisioned the Y-factor to be suitable after using a MAC-curve.

Y-factor as a reference curve

The Y-factor currently consists of 24 abatement options that are scored on their implementation complexity using 12 barriers. This information was used to create a global reference curve. Because the criteria are of a qualitative nature and only scored on a 3-point scale, and the abatement options are scored within a global scope, some participants questioned its suitability for mimicking real-world complexity. All participants agreed that the Y-factor would be able to explain complexities best on a national level. Different than for marginal costs alone (as is the case with the MACC), the implementation complexity in the Y-factor is more geographically bound. A main reason for this is that laws and regulations can differ strongly per country, which influences the complexity of implementation on multiple aspects. Furthermore, multi-actor situations are organised differently per country, the physical landscape differs and finally, most climate policy is formulated on a national level rather than on a supranational level.

As mentioned briefly in the introduction of section 3, the participants were introduced to a web-based tool that displayed the Y-factor digitally. It was also provided with the options to change values of Y-factor barriers or to attach relative weights to barriers in order to highlight increased complexity of tackling certain obstacles. These options were regarded as interesting, but multiple participants were hesitant with regards to its added value. They were afraid that the reliability, and with that part of its added value, would be lost if the users of this tool would be given freedom to change relative weights.

Where participants were critical on some aspects of the Y-factor reference curve, most of them were very enthusiastic on the Y-factor MACC scatterplot graph. The scatterplot, showing the complexity of the Y-factor, combined with the abatement potential and marginal costs from the McKinsey MACC was highly valued by all interviewees, because of its ability to capture a lot of information, whilst remaining easy to understand.

Generating discussions

"*This could have been very interesting for the negotiations for the Dutch climate agreements* ". This quote came from one of the focus group sessions. It was part of a conversation on how to make best use of the Y-factor's information. It was recognized by participants that nowadays, many discussions on implementation complexities often lack a structure, which makes it hard to reach a consensus. The Y-factor allows for the comparison of different abatement options on the exact same criteria. In this way it can be prevented that policymakers have two different conversations using different arguments. Another interviewee mentioned how the Y-factor would be "*interesting to use to collaboratively come to a consensus on the most complex issues to address*".

During the focus groups, it was observed that the discussions needed to be triggered by the moderator and did not always appear spontaneously. The discussions that turned out the most productive, originated when comparing different abatement options. Addressing and discussing Y-factor values of one specific abatement option did not lead to many discussions. Participants mentioned that they had insufficient knowledge to call values into question.

Room for improvement of Y-factor

During the interviews and focus groups, feedback was given on the Y-factor method, regarding the choice of factor distinction, factor levels and scoping of abatement options. With regards to the choice and segregation of the twelve Y-factor barriers, there were two points that were discussed extensively. First, during two of the interviews, the increased complexity due to to laws and regulations was stressed. This is not incorporated as a factor, partly because different laws have influence on different barriers. Second, a doubt was risen on whether the Y-factor was specific enough with scoring on 3 levels per factor only. One participant was convinced that this was not the case, and at the TU Delft focus group this doubt was shared. When this distinction was addressed at the CE Delft focus group, there was an understanding for this doubt. However, they envisioned that specification to a 5 or 7-factor level would lower the validity of the scores, because the complexity would for many abatement options be too hard to indicate. A final notion on this point by a participant of the CE focus group, was how the Y-factor would become more relevant if more expert opinions would be collected on a 3-factor level and showing a confidence interval, rather than increasing the amount of scoring categories to 5 or 7.

All of the participants acknowledged the importance of the barriers that constitute the Y-factor. However, the barriers were not always easily distinguished. In three cases, a participant addressed the relative importance of accounting for local resistance. All three times, the participant was looking for the factor addressing local resistance within the category of behaviour, whereas the multi-actor complexity should have been addressed. It is therefore recommended to either create a manual on how to use the Y-factor or to ensure a moderator is present on the first occasion that the Y-factor

is introduced to new users.

5. Conclusion

This research showed that the Y-factor can definitely have its added value for policymakers. Although there is an increasing awareness that the choice for options to reduce GHG emissions cannot be solely built upon financial considerations, policymakers acknowledge that there is currently no suitable alternative that incorporates more aspects. Within the early stages of the policymaking process, the Y-factor could become a respectable method to provide an integral and structured way to assess carbon abatement options and to facilitate discussions with policymakers. The Y-factor has the potential to present a high-level overview indicating the implementation complexity of a wide range of abatement options. This information is suitable to function as a starting point for policy discussions. Asked for the best application of the Y-factor and its supporting tool, policymakers advised to construct reference scores and reference Y-factor curves on a national level. This is because the majority of carbon abatement policies are formulated on a national level, and moreover, because most of the considered complexities are very context-specific. Context-specific in the sense that laws and regulations are often determined on a national level, and that the organisation in terms of involved actors are too.

Apart from the creation of national reference curves, it is recommended to further develop the Y-factor by clarifying the implementation barriers in order to prevent misunderstandings. Moreover, scoring more abatement options and further validating the current options would increase the reliability and usability of the Y-factor.

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