Advanced Carbon Capture
for steel industries integrated into CCUS Clusters

Innovation Action

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D6.4. Report describing business model innovation framework design and scenario-analysis results.

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CI	*Classified*

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1. Version log

Version	Date	Released by	Nature of Change
0.1	February 2023	M Covarrubias (RU)	First Version
0.2	March 2023	Milan Elkerbout (CEPS)	Review
1.0	June 2023	M Covarrubias (RU)	Final

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2. Definition and acronyms

Acronyms	Definitions
BM	Business Model
BMI	Business Model Innovation
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CCUS	Carbon Capture, Utilization and Storage
CCfD	Carbon Contracts for Difference
CO2	Carbon Dioxide
EII	Energy-Intensive Industry
ETS	Emissions Trading System
EU	European Union
H2	Hydrogen
OPEX	Operational Expenditure
O&M	Ownership and Management
RET	Renewable Energy Technologies

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3. Introduction

Adopting CCUS by the energy-intensive industry (EII) requires innovating existing business models. In innovating business models is crucial to observe how emergent or existing elements of business models are configured under different technological, socio-political, and environmental conditions. This becomes particularly relevant in the context of the Dutch and Belgian (EII) sector, which aims at finding innovative business models that facilitate the still complex adoption of CCUS. These conditions, and their circumventing policy environment, are fast changing. This deliverable reports on the perceptions as collected from the relevant actors who participated during the development of the present undertaking.

Adopting carbon capture, utilization and storage (CCUS) to decarbonize the EII is necessary to respond to climate change mitigation targets. While CCUS is necessary it is also a challenging technological choice. CCUS comes with uncertainties regarding high upfront investments, monetization challenges, cost avoidance business models conditioning, its commercial readiness, technological lock-in, the liability of CO2 captured, risks involved in failing to accomplish emissions reduction targets, and the availability of effective policy instruments helping to support its adoption (see discussions in (Nilsson et al., 2021)). On a similar note, 'Muslemani et al. (2020) considers CCUS as a new technology for which there is no existing business model. For a business model to be viable, the cumulative revenues must go beyond aggregated costs that occurred during the creation and delivery of value to the customers.' (Janipour et al, forthcoming). As previously identified in Deliverable 6.3 and observed in the literature, the lack of viable business models has been proposed as one of the main reasons hindering the adoption of CCUS in the industry sector (Element Energy, 2018; Janipour et al forthcoming; Muslemani et al., 2020).

Deliverable 6.4. aims to offer a Business Model Innovation (BMI) framework and potential scenarios of change. The objective of the deliverable is twofold. First, a framework is developed and validated to describe the development of the business model configuration of elements and their interrelationships to enable the adoption of Capture Utilization and Storage (CCUS) technologies. Second, it offers a Scenario-analysis which is used to forecast potential economic, technological, and socio-political developments that may make an alternative business model more feasible to unfold by 2032 to adopt Carbon Capture Utilization and Storage (CCUS) by industrial emitters. The report concludes by providing a set of innovation descriptions, potential investment funding strategies, revenue models, cash flow structures, and risk analysis, all part of the Business Models (BM) that enable the adoption of CCUS. Deliverable 6.4 then, aims at shedding light on the potential long-term futures to which the business model might unfold (a general goal of WP6). In doing so, novel business models and scenarios were formulated in close consultations with stakeholders in the North Sea Port CCUS cluster. Key elements discussed during the consultations include the assessment of risks and

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barriers to the deployment of industrial carbon capture and transport and storage infrastructure, cash flow, risk management instruments, appropriate funding sources, capital financing, and ownership structure.

This report is structured as follows. **Chapter 4,** describes de activities carried out and the results of this report. The methodology utilized in this report. **Chapter 5**, provides concluding insights into what would it take for industrial emitters to support the adoption of CCUS.

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4. Methodology

4.1. A Delphi approach to the focus group method

The Delphi method is an effective and proven method for conceptual framework development (see literature review in ((Okoli & Pawlowski, 2004); Egfjord & Sund, 2020)). Innovating BM might have consent-related issues in the sense of stakeholders have different problem definitions, targets, and business and environmental objectives. What Delphi brings on board then, is a structured methodology to guide stakeholders through the co-designing of a conceptual framework while observing constructive critical thinking and reflection. Moreover, it aims at providing consensual decision-making and design processes in the making of innovation frameworks.

The added value of utilizing a Delphi approach is that it helps to reach a consensual decision-making process between stakeholders (see discussions in (Egfjord & Sund, 2020). Due to the sensibility of the topic and the information held by stakeholders, Delphi offered anonymity between participants and helped to avoid bias and confrontation "to achieve the most reliable consensus on a given topic among a group of experts" (Egfjord & Sund, 2020, p. 3). By following Egfjord & Sund (2020); Lüdeke-Freund et al. (2018); Okoli & Pawlowski (2004); and Schmidt (1997), this report obtained, anonymously, individual answers from a group of experts within a set of two repeated interventions. The first round aimed to provide the researcher with the main trends deriving from the respondents' answers and perceptions. (See Interview Guidelines for the items and topics list). This served as the background for a second round in which respondents, anonymously, were presented with the results of the main trends as found during the first round of intervention. In the second round, the respondents were approached again with the same set of questions.

The main difference between the rounds is that during the second one, the participants were aware of all the answers from all participants, anonymously (employing a summary and presentation of the findings from the stakeholder's interviews). Such a symmetry of information between participants aimed to encourage participants to provide a more consensual and richer answer as a result of "their multiple iterations and their response revision due to feedback" (Okoli & Pawlowski, 2004, p. 20). In this way, our study shed light on what elements are crucial in different environmental contexts for stakeholders in the industry to decarbonize through adopting CCUS. Furthermore, it facilitates achieving the ultimate objective of the C4U research (Task 6.5 is to arrive at three short-listed alternative innovative business models). In more detail, it consisted of the following eight steps.

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The 8 Steps.

1. *Identifying key experts (first round).*

One of the most critical requirements is the selection of qualified experts.' (Okoli & Pawlowski, 2004, p. 17). We considered stakeholders to be key actors holding relevant knowledge, influence, and interest in the status quo of the steel, iron, and chemicals industries, and with a stake in the adoption of CCUS technologies in the North Sea Port cluster located in The Netherlands and Belgium. Taking a multi-actor governance perspective based on the stakeholder identification approach including relevance, power, and urgency suggested by Mitchel et al. (1997), relevant stakeholders categories were found to be emitters, technology developers, transport and storage providers (infrastructure), research institutes, governmental bodies, and policy and decision-makers -all with a stake in CCUS and industrial decarbonization (Mitchell et al., 1997). Having an identification process helped increase the chances of having involved the most qualified participants available, as Okoli & Pawlowski (2004) recommend.

Stakeholder experts

In alignment with the guidelines of Delbecq & Ven (1975), Mitchel et al. (1997), and Okoli & Pawlowski (2004), the study used the next steps to identify relevant stakeholder experts:

- Governance actors mapping to identify the experts' governance network.
- Preparation of a list of contacts having a stake and knowledge of CCUS and industrial decarbonization. This step involved categorizing stakeholders into categories (researchers, policy and decision-makers, practitioners, infrastructure, and technology developers).
- Populating the list with the names, categories, and contact details of the potential participants.
- First-round contacts. We contacted the identified stakeholders and ask them to nominate others.
- Ranking experts by qualifications. In this step, we made a final list of stakeholders to be invited to participate based on their relevant stakes and expertise.

Population Size and Sampling

Using group dynamics logic for arriving at a consensus among experts following (Okoli & Pawlowski, 2004, p. 19) experts were selected. Due to the emergence characteristic of the adoption of CCUS technologies and the nature of this research (study the innovation of BM to support a technology that is not commercial or deployed yet) the population size of experts in the domain was limited. Consequently, considering the emerging nature of CCUS (limited

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number of experts), we opted for having as many experts as they were willing to participate after their identification and invitation (n=13) but bounded by focus group session limits. See in Table 1 a list of interviewees.

Table 1: List of interviewees

Stakeholder category	Organization
CCUS adopter (industry)	Arcelor Mittal
CCUS adopter (industry)	Arcelor Mittal
CCUS adopter (industry)	Dow
CCUS adopter (industry)	Zeeland refinery
CCUS adopter (industry)	Engie
CCUS adopter (industry)	Shell
Technology and infrastructure developers	EBN
Technology and infrastructure developers	Shell
Policy makers & Regional authorities	Dutch ministry of economic affairs & climate policy
Policy makers & Regional authorities	Flemish Agency for Innovation and Entrepreneurship
Policy makers & Regional authorities	NSP authority
Research institutes	TNO
Research institutes	TNO
Research institutes	PBL

Organization: Panel division.

We identified four relevant categories of experts possessing important and valuable knowledge about BMI for CCUS: applied research institutes, practitioners, government officials, and technology and infrastructure providers/developers. As expected, these groups had somewhat different perspectives. To obtain a reasonable degree of consensus in mind, we

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approach each group separately. Doing so, allowed for a comparison of the perspectives between the different stakeholder groups, as suggested in Okoli & Pawlowski (2004).

2. *Designing the questions for use in the first Delphi round.*

Based on a literature review to identify the current BM elements relevant to the adoption of CCUS and industrial decarbonization, the interview questionnaire (see Annex 1) was developed consisting of semi-structured questions to guide the respondents. The purpose of the questionnaire is to elicit knowledge about current and future elements perceived to have a significant impact on business model innovation to support the adoption of CCUS.

Thereafter, the first round of questions was administered separately for each group of experts (see Step 1). The outcomes were used to reflect on the BMI framework and to feed into the scenario and market analyses.

3. *First Round of Delphi with experts: conducting interviews.*

13 semi-structured interviews with stakeholders were conducted. The interviews took place online or in-room from December 2021 until April 2022. All the interviews were recorded and transcribed (See the above list of interviewees in Table 1). During the interviews, the interviewees were asked to explain their reasoning and take on the topic. In this round, the experts were treated as individuals and the goal was to identify as many elements influencing the adoption of CCUS.

4. *Analyzing the results of the first round of questions.*

We discussed each topic and trend among the answers provided by the respondents. From this step, a set of elements of BM describing the business model innovation framework was constructed. The full framework is described in the ***'Report summarising stakeholder analysis to identify key drivers and challenges of the key players (Task 6.3)'*** and in the (submitted) journal article under the title ***'Business model framework to the adoption of CCUS in energy-intensive industrial clusters'.*** Both, the report and article were key documents to elaborate on the following step.

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5. & 6. Second Round of Delphi with experts in a focus group session

For the second round of the Delphi methodology, we use a focus group session following the suggestions as developed in the literature by O.Nyumba et al (2018). A focus group is a suitable method for validating the BM framework, and its elements and arriving at a consensual understanding of what it takes to adopt CCUS from the stakeholders' views. This method is well-known in the literature for allowing the researcher to combine interviewing, observations, and group interaction to obtain an in-depth understanding of social issues (O.Nyumba et al., 2018). For the convenience of meeting the participants' calendars and to avoid unnecessary traveling-related emissions, the session was conducted online.

The focus group followed the next steps, as developed in O.Nyumba et al (2018).

a. Presenting the list of BM elements and innovation framework to participants.

First, we presented the business model innovation framework including the list of business model elements constructed from the first round of intervention to the stakeholder participants to validate it. (See 'Report summarising stakeholder analysis to identify key drivers and challenges of the key players (Task 6.3)' and the results from 'Business model framework to the adoption of CCUS in energy-intensive industrial clusters' (Janipour et al Forthcoming). Participants from the first round were contacted and invited to participate in the online session. As discussed in the literature by Egfjord & Sund (2020, p. 3), '[t]here will always be a risk of participant dropout in this kind of study, with typical dropout rates of 15–25%'. In this research, the first round gathered the participation of 13 stakeholders. For the second round, 6 stakeholders showed interest. (See Table 2 below).

b. Discussing and ranking BM elements.

Once the participants were presented with the business model framework, the focus group session was structured in the next steps (following O.Nyumba et al (2018)) to collect data:

Table 2: List of participants for the Focus Group

Stakeholder category	Organization
CCUS adopter (industry)	Arcelor Mittal
CCUS adopter (industry)	Arcelor Mittal
Policy makers & Regional authorities	Dutch ministry of economic affairs & climate policy
Research institutes	TNO
Research institutes	TNO
Research institutes	PBL

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a) We defined the main objective of the study to validate the BMI framework and to rank and collect the participant's views on how business model elements interact and help best to adopt CCUS.
b) The participants were asked to answer a set of questions as presented in the first round of this methodology.
c) We presented BM elements and proposed combinations and dynamics of elements to arrive at business model options.
d) The participants were asked to validate the BM elements and the BMI framework.
e) The participants were asked to rank each BM element, on a Likert scale from 1 (not important) to 5 (very important).

7. Analyzing the data of the second Delphi-method round (focus group)

We discussed each trend separately and identify any change in the perceptions of each respondent or group. The researchers collected the ranking as developed by the respondents including their arguments to arrive at such rankings.

8. Ordering the ranking of the elements by importance score and shortlisting (by researchers).

We listed and trimmed down elements with a mean importance score shorter than four to identify the elements (and dynamics) that each group considered to be most crucial. We employed a higher cut-off point because the goal was to identify features for which there was an agreement regarding the presence and importance of elements within each expert group. (see methodological observations in (Egfjord & Sund, 2020)).

With these steps and results in place, we further guide stakeholders to structurally envision potential scenarios in which the adoption of CCUS could unfold by 2032.

4.2. Scenario-Analysis: forecasting the likelihood of scenarios to unfold up to 2032

We employed a Scenario-analysis to forecast potential economic, technological, and socio-political developments that might unfold in the period up to 2032 when aiming at adopting Carbon Capture Utilization and Storage (CCUS) by industrial emitters. Scenario analysis is an effective methodology to shed light on either a predictive, explorative, or normative view either in the short, medium, or long-term (Börjeson et al., 2006). Predictive scenarios aim to shed light

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on what is likely to happen in the future. Forecasts and what-if scenarios are the main two types of predictive scenarios (Börjeson et al., 2006). In doing so, we aim to shed light on how innovative business models help to arrive at different scenarios. This analysis followed **4 phases** of elaboration as suggested by Krueger et al. (2001).

Phase 1. A baseline analysis of the present situation and aim.

The baseline analysis aimed to provide a structured description of the present situation, dynamics, and trends, including relevant policies to support the adoption of CCUS. The analysis aims to allow for comparing the baseline (present situation) with the future perspectives further in the process (external scenarios). An important element of the analysis is to identify the specific planning task at hand. Usually, spatial planning processes start with a fuzzy idea of the planning task at hand. The baseline analysis should allow for arriving at a more detailed description and selection of a more specific scenario in which BMI supported the adoption of CCUS. We used data as provided in the *'Report summarising stakeholder analysis to identify key drivers and challenges of the key players (Task 6.3)'* and from the (submitted) journal article under the title *'Business model framework to the adoption of CCUS in energy-intensive industrial clusters'.* Moreover, the baseline was further informed on a first round of interviews with stakeholders (see 4.1, The 8 Steps).

Phase 2. The development of external scenarios.

Phase 2 unfolds into two steps. To inform Step 1, we used data as provided in the *'Report summarising stakeholder analysis to identify key drivers and challenges of the key players (Task 6.3)'* and from the (submitted) journal article under the title *'Business model framework to the adoption of CCUS in energy-intensive industrial clusters'.* Report (D6.3), informed this Phase with insights on relevant trends such as assessment of risks and barriers to deployment of industrial carbon capture and transport and storage infrastructure, cash flow, risk management instruments, appropriate funding sources, capital financing, and ownership structure.

Step 1. Identifying Driving Forces

a) Identifying relevant driving forces (trends)
b) Impact-Uncertainty Matrix

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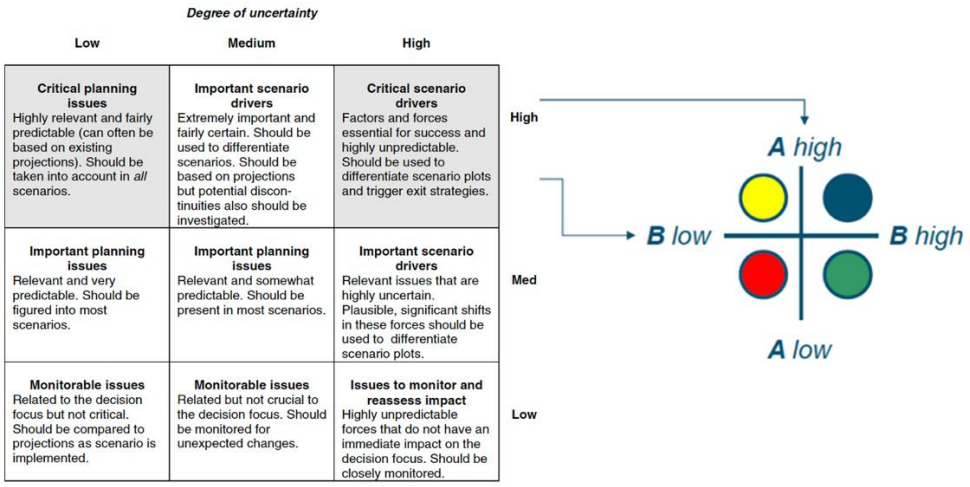
Step 2. External Scenarios

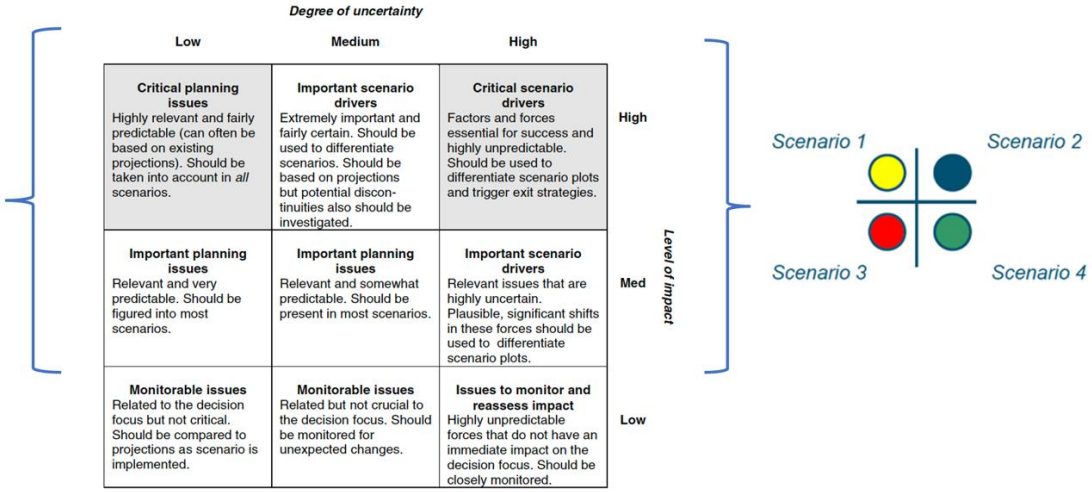
a) Critical Scenario Drivers – high degree of uncertainty and high degree of impact (Figure 2).
b) Developing scenarios (Figure 3).

Figure 2: Deriving Scenario Drivers from Impact-Uncertainty Matrix (Krueger et al., 2001).



	Degree of uncertainty: Low	Medium	High
	Critical planning issues Highly relevant and fairly predictable (can often be based on existing projections). Should be taken into account in *all* scenarios.	**Important scenario drivers** Extremely important and fairly certain. Should be used to differentiate scenarios. Should be based on projections but potential discon-tinuities also should be investigated.	**Critical scenario drivers** Factors and forces essential for success and highly unpredictable. Should be used to differentiate scenario plots and trigger exit strategies.
High			
	Important planning issues Relevant and very predictable. Should be figured into most scenarios.	**Important planning issues** Relevant and somewhat predictable. Should be present in most scenarios.	**Important scenario drivers** Relevant issues that are highly uncertain. Plausible, significant shifts in these forces should be used to differentiate scenario plots.
Med			
	Monitorable issues Related to the decision focus but not critical. Should be compared to projections as scenario is implemented.	**Monitorable issues** Related but not crucial to the decision focus. Should be monitored for unexpected changes.	**Issues to monitor and reassess impact** Highly unpredictable forces that do not have an immediate impact on the decision focus. Should be closely monitored.
Low			

Figure 3: Input to inform the 4 Scenario Quadrants (Krueger et al., 2001).



	Degree of uncertainty: Low	Medium	High
	Critical planning issues Highly relevant and fairly predictable (can often be based on existing projections). Should be taken into account in *all* scenarios.	**Important scenario drivers** Extremely important and fairly certain. Should be used to differentiate scenarios. Should be based on projections but potential discon-tinuities also should be investigated.	**Critical scenario drivers** Factors and forces essential for success and highly unpredictable. Should be used to differentiate scenario plots and trigger exit strategies.
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Med			
	Monitorable issues Related to the decision focus but not critical. Should be compared to projections as scenario is implemented.	**Monitorable issues** Related but not crucial to the decision focus. Should be monitored for unexpected changes.	**Issues to monitor and reassess impact** Highly unpredictable forces that do not have an immediate impact on the decision focus. Should be closely monitored.
Low			

Level of impact

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Step 3. Impact of External Scenarios

a) Describe the impact of the trends in each scenario

Once the four external scenarios to which **technological, economic and institutional (socio-political), and environmental** developments might unfold concerning the adoption of CCUS in 2032, a vision to arrive at an ideal scenario was created.

Phase 3. Creating a vision for the future (to arrive at the ideal scenario).

Visions of the future

The third stage of the scenario technique entails creating one or more future visions. A vision tells a logical storyline or narrative of a desired future that policy and decision-makers can recognize and relate to (see discussions in (Maack 2001, Sandercock 2003). We settled the present situation as t_0=*2022* and t_x=*2032*. The visions of the future aim then to fill in the gap between t_0 and t_x (see Figure 3). Following the recommendations as developed by (Schwartz 1991), we defined end-states and targets to guide the framing of visions. For example:

- Winners and losers
- Challenges and responses
- Evolution and revolution (disruptive)
- A vision supported by a BMI option for the future business organization of CCUS in The Netherlands and Belgium.

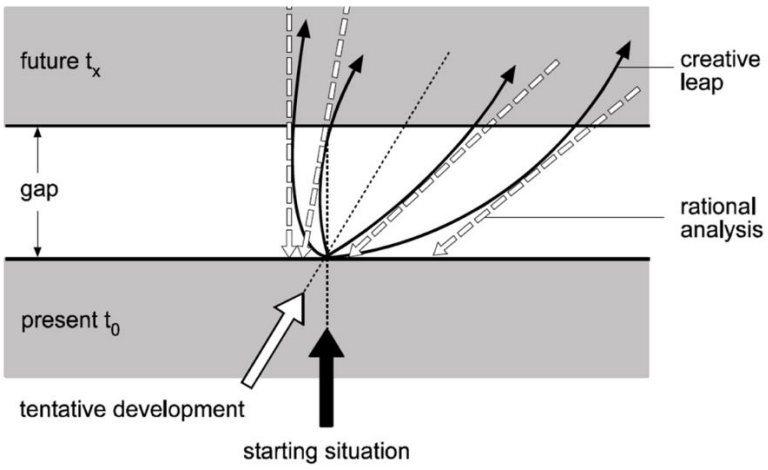

Figure 3: Creative leaps into the future (Kleefmann, 1985).

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Phase 4. Formulating policy strategies.

In Phase 4, the researchers confront the visions (as developed in Phase 3) with the different future environments as described in the external scenarios. In doing so, a SWOT analysis guided what policies and strategies might be needed to arrive at an envisioned scenario (see Figure 4).

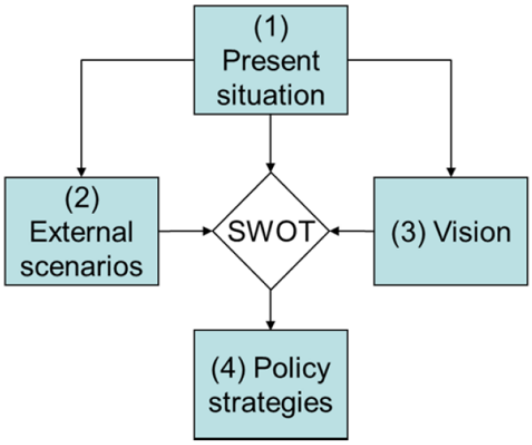

Figure 4: Swot analysis to inform policy strategies to arrive at the envisioned scenario (Carsjens, 2013)

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5. Results

Business Model Innovation Framework

Starting point: A generic Framework

Chesbrough, (2002); Shafer et al., (2005); Watson, (2005) identify five different generic elements in business models. These are value proposition, market segment, value chain structure, revenue generation and margins, and position in the value network (See Figure 5). Nevertheless, employing CCUS comes hand in hand with specific (and innovative) business model elements that enable its adoption. As previously identified in 'Deliverable 6.3' and observed in the literature, the lack of viable business models has been proposed as one of the main reasons hindering the adoption of CCUS in the industry sector (Element Energy, 2018; Janipour et al forthcoming; Muslemani et al., 2020).

Figure 5: A generic framework of Business Model Elements

Stakeholders engagement: Basic configuration of elements

To expand on the actual needs of stakeholders concerning the lack of current business models to facilitate de adoption of CCUS, we engage with stakeholders to collect data to develop a Business Model Innovation framework. Figure 6 presents the elements of BM as observed from

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the first round of intervention according to this methodology. This figure illustrates the current elements identified by the stakeholders as not having the potential to support the adoption of CCUS. The main missing element in the current configuration of BM elements is a revenue model separated from a cost structure. The cost structure responds to a carbon market to which capturing firms can relate. but the revenue model addresses revenue streams from sales generated for example from a premium price of green steel or CCU.

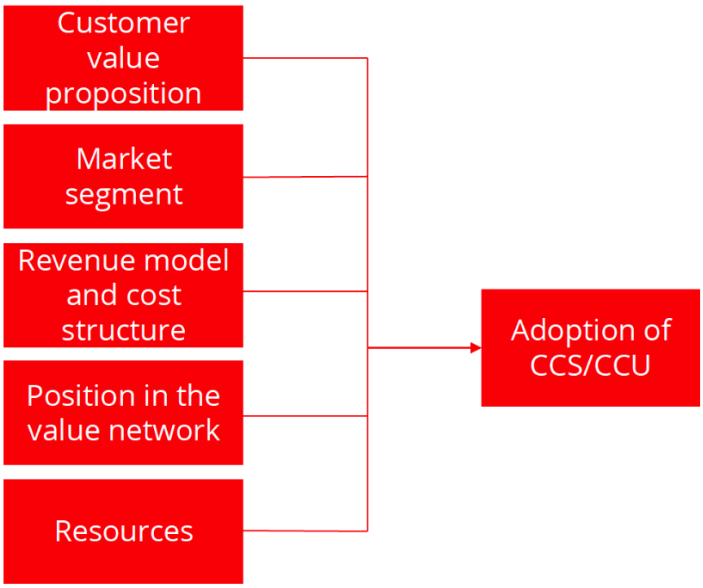

Figure 6: Current Business Model Elements

BMI framework: configuration of elements

Figure 7 presents a visualization of the BMI framework based on stakeholder input see (Janipour et al, forthcoming). The main changes in this BM are twofold. First, a clear distinction between the revenue model and cost structure elements. Second, the aggregation of Ownership is a necessary element to consider to adopt CCUS.

Revenue Model

A Revenue model that facilitates the adoption of CCUS provides income to firms by having additional sales of premium price products (e.g. green iron) or selling captured CO2 for utilization to third parties. In general, stakeholders perceive it as necessary to first enhance the viability of CCS projects, to then set up market conditions to develop CCU projects as a second step. De-risking green electricity projects by CCU projects and avoiding costs of CO2 by CCS (based on the EU ETS) are the main strategies to define a cost structure that helps emitters to

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adopt CCUS. A CCU project is perceived to lower the risk of green electricity projects due to the sharing costs potential and providing an alternative to the lack of agreements on green electricity projects.

Ownership

With regards to Ownership - the possession of resource endowments such as technologies - a clear division and allocation of ownership through the different steps of CCUS is envisioned. One of the main concerns for emitting firms is to keep the ownership of capturing technologies. On the other hand, both, external parties and emitting firms prefer the former to keep the ownership of the transport and storage technologies, and related infrastructures and facilities.

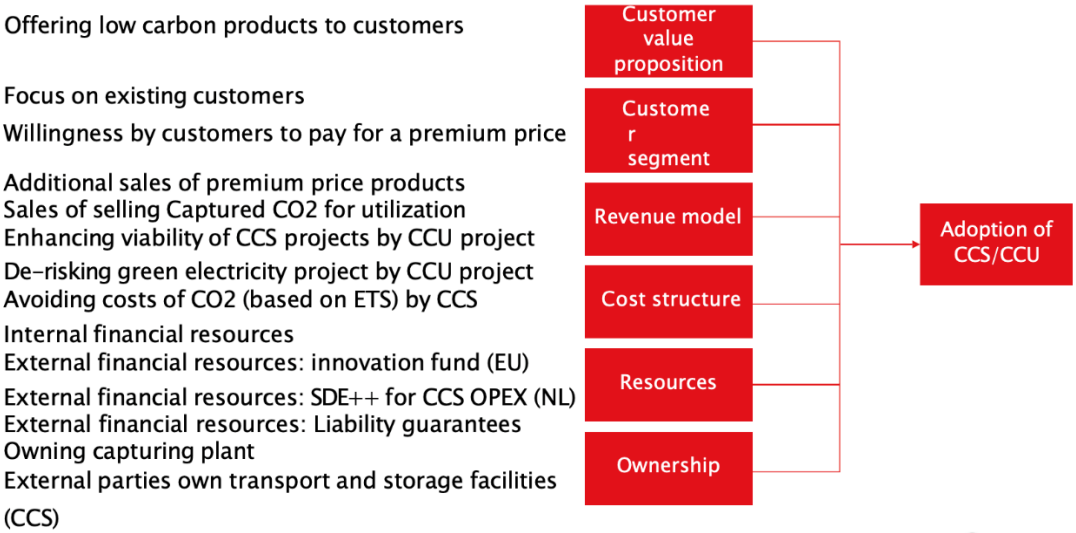

Figure 7: Business Model elements supporting the adoption of CCS/CCU

BM Options with the potential to adopt CCUS

Muslemani et al (2020) analyzed business models of existing large-scale CCUS projects around the world. They explored the challenges and needs of implementing CCUS in the industry. Their results show that 'the revenue model is the most critical element to building successful CCUS business models, around which the following elements are structured: funding sources, capital & ownership structure, and risk management/allocation.' (Muslemani et al., 2020, p. 1). Moreover, four innovative business model options are proposed as having the potential to close the revenue stream gap which has been identified as one of the main barriers to adopting CCUS. Vertically Integrated, Joint Venture, Operator, and Transporter business

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models are options having the potential to help adopt CCUS (Muslemani et al., 2020). These are described and illustrated as follows.

Vertically Integrated CCUS Business Model

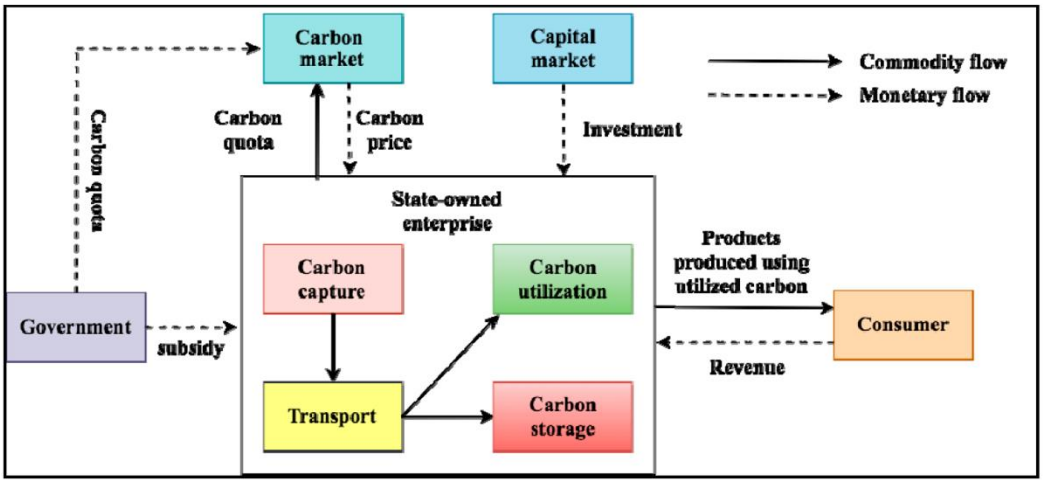

Figure 8: Vertically Integrated CCUS Business Model

Figure 8 'depicts the structure of a generic vertically integrated CCUS model which may be applicable in both the industrial and power sectors.' (Muslemani et al., 2020, p. 13). In this business model 'operations are vertically integrated in this self-build model, where industrial or power companies use their technical and commercial capabilities to support and link each element of the CCUS chain.' (Muslemani et al., 2020, p. 13). 'Here, the company must operate capture and storage/utilization sites as well as have means of transportation and must also be integrated to a high degree. This in effect limits market players to only specific enterprises with the resources to invest heavily in and manage an entire CCUS chain. This, however, alleviates the risks associated with synchronizing efforts among different sectors. (Muslemani et al., 2020, p. 13). 'The high degree of integration also serves to eliminate transaction costs as CO2 is directly transported from the capture plant to be utilized.' (Muslemani et al., 2020, p. 13). The revenue generated in this model comprises:

1. revenue from CO2 utilization, and where applicable, either
2. a direct subsidy for CO2 storage from the government and/or
3. revenue from selling extra carbon emission credits in the carbon market.

(Muslemani et al., 2020, p. 13).

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Joint Venture CCUS Business Model

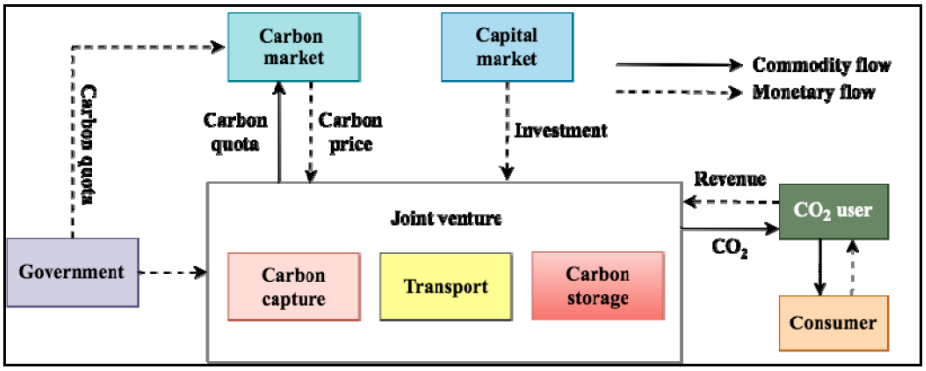

Figure 9: Joint Venture CCUS Business Model

As shown in Figure 9, the Joint Venture CCUS Business Model is 'based on a partnership between the industrial/power company and external CO2 users or storage consultants. The industrial company may be liable for costs and operation of CO2 capture, but transport and storage would be managed jointly, resulting in a more equitable distribution of risks and revenues.' (Muslemani et al., 2020, p. 14).

Operator CCUS Business Model

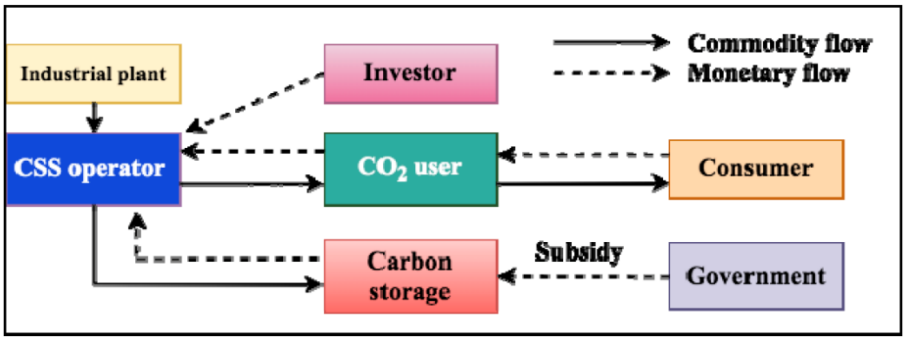

Figure 10: Operator CCUS Business Model

As illustrated in Figure 10, 'In this pay-at-the-gate model, an industrial/power company cooperates with a third party featuring high technical and engineering capabilities to handle the CO2 after it has been captured. The third party will then, for an agreed fee, appraise different utilization/storage options and take the responsibility for transporting the CO2.' (Muslemani et al., 2020, p. 14).

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Transporter CCUS Business Model

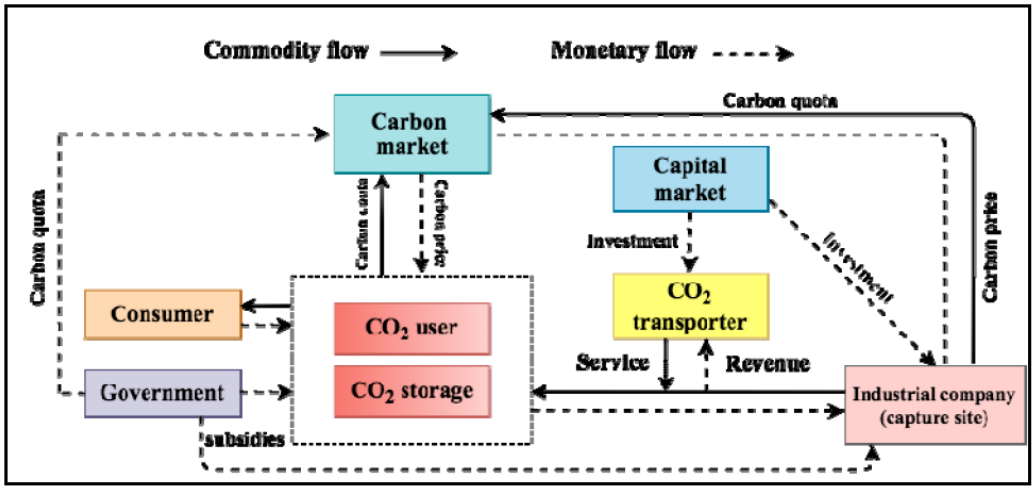

Figure 11: Transporter CCUS Business Model

As illustrated in Figure 10, the Transporter CCUS Business Model entails that 'a third party is only responsible for the transportation part of the CCUS chain. The industrial/power company is responsible for capturing CO2, including covering capture equipment and O&M costs, and generates revenue from CO2 sales and trading carbon credits. The transport company covers the costs of transport equipment and their O&M and charges a fixed fee for CO2 transport, one which is pre-agreed upon among the stakeholders. Finally, the CO2 user covers CO2 purchasing costs and costs associated with utilization or storage equipment and their O&M. (Muslemani et al., 2020, p. 15).

Presenting, validating, ranking, and ordering BM elements and BM options.

Presenting the BMI framework

On the 12th of January 2023, stakeholders who participated in the Delphi session ranked, discussed, and validated the presented BMI framework, its BM elements, and the set of different BM options.

Validating and Ranking the BMI framework and elements

Are the current business model framework elements relevant or are some of these elements redundant/missing? Table 5 provides the ranking of the different BMI framework elements. It summarizes the observations from the participants on each specific element and ranking. As

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identified in Table 5, elements such as Costumer Value Proposition and Ownership received the lowest ranking (2.5/5). The resources and Revenue Model received the highest rankings (4.5/5).

Table 5: BMI framework elements ranking

BM elements	Ranking	Observations from the focus group discussion
Customer value proposition	2.5	• Temporal dimension (e.g. green commodities might benefit from a premium price at present time but not in the future when green commodities become mainstream. Change of importance of issues in later phases (e.g. green premium diminishing marginal returns)[1] • Willingness to pay a premium for CCU depends on what it replaces • World competitive vs locale scale perspective. • Competition between and/or complements of CCS/CCU in the short vs long term. • CCS is an enhancer of CCU. • Grey or green CO2 captured may make a difference (e.g. green is for example waste converter). • Intrinsically linked to the revenue model. There is a low value placed on this from the industry – a solid revenue model irrespective of customer value is far more significant.
Customer segment	4	• From a CCUS perspective – low importance. • Focus is on the existing customer segments. • Some niche cases are where customers are willing to absorb costs in a premium product. In general, complete reliance is not placed on this in the business models.
Revenue Model	4.5	• Highlight differences between revenues from product sales through premium price part and funding from government (resources) and also distinction with cost structures. • Considering the risk of high costs from ETS this is quite relevant. • There is no project without a concrete revenue model and cost structure. The Resources and Customer Value Proposition are both linked to the revenue model in practice.
Cost structure	3.5	• Avoiding CO2 costs is more important than avoiding energy costs • For the steel industry, the cost of energy is likely to be the most significant driver in Europe.
Resources	4.5	• Financial managers are concerned with the temporality of finance support. One-off CAPEX and short-term OPEX support are likely not

[1] Some elements of BM that depend on public policy or subsidies may be completely feasible/acceptable in the short term. However, in the long-term such incentives might lose their acceptance.

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		to be enough to completely absorb the costs of decarbonization. Internal financial resources are limited, particularly in the steel industry where profit margins are low and investment requirements are high.
Ownership	2.5	• Important for the industry to keep ownership of CO2-capturing technologies on-site. (Having control on the assets is preferred. More control over uncertainty and liabilities). • Ownership is '*really quite important as well*' – questions on third-party access to transport infrastructure. • Emitters' responsibility seems to stop at the gate. Emitters do not foresee anything on storage liability. • Emitters do not foresee anything on CO2 accounting for CCU. For CCU to produce a product from CO2, need to compare it to a reference product. Challenging to understand the benefits of CCU. • Little appetite/responsibility for storage and transport. Missing appetite for businesses to engage in transport and storage. Even if economic incentives are high enough, the commitment to do CO2 storage and having this long-term vision can be a barrier to engaging in CO2 storage – upfront risk + need to operate the field for 10-20 years + legal requirement to look after it for another 10-20 years. This kind of setup is only interesting to major oil and gas players, not smaller oil and gas players. However, many of the economic incentives are already there. There are other factors at play that act as a barrier to investment. • Storage and transport require a long-term commitment. • The importance of owning the infrastructure varies by company. Likely to be less important; however, some companies may wish to have more control over the process. • Without ownership, additional risk is assumed. Proprietary innovations and learnings may be restricted. • Ownership of the capture plant is influenced by the operation of the steel plant.
Ranking: 1 = not important; 2= low importance; 3 = medium; 4 = important; 5 = very important		

As shown in Figure 7, the Revenue Model and Ownership were highlighted as important elements to consider when innovation business models support the adoption of CCUS. When validating the BMI framework, Revenue Model and Resources (4.5/5), and Ownership (2.5/5) received special attention from participants as further described below.

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Validating Revenue Model element

As initially included in the BMI framework, a Revenue model that enables the adoption of CCUS provides income to firms by having additional sales of premium price products (e.g. green iron) or selling captured CO2 for utilization to third parties. On a similar note, de-risking green electricity projects by CCU projects and avoiding costs of CO2 by CCS (based on the EU ETS) are the main strategies to define a cost structure that helps emitters to adopt CCUS. These initial notions became validated by the participants.

The participants suggested further insights to refine the elements of the Revenue Model. These include a) highlighting differences between revenues from product sales and funding from government (resources), b) having a clear distinction between products sales and funding, and the cost structure element of a business model, and c) emphasizing the importance and potential risk of high costs from current and future ETS pricing. Further thoughts point out the interdependencies between the Revenue Model, Resources, and Customer Value Proposition in use practice.

Validating Resources element

The participants put forward concerns related to the temporality of external financial support. One-off CAPEX support and short-term OPEX support are likely not to be enough to completely absorb the costs of industrial decarbonization. Regarding internal financial resources, these are seen are limited particularly in the case of the steel industry where profit margins are low and investment requirements are high.

Validating Ownership element

As anticipated in the BMI framework, the Ownership element represents providing a clear division and allocation of ownership through the different steps of CCUS. Specifically, one of the initial concerns for emitting firms was to keep the ownership of CO2 capture technologies. On the other hand, both external parties and emitting firms preferred the external parties to keep the ownership of the transport and storage technologies, and related infrastructures and facilities. These initial observations became validated by the participants.

Although the participants ranked this element with the lowest qualification (together with Customer Value Proposition), the participants emphasize the importance of Ownership. Some observations include a) ownership is '*really quite important*', b) emitters' responsibility should stop 'at *the gate*' (e.g. not owning any liability on transport and storage), and having a preference to not engaging in transport and storage. Moreover, the participants highlighted that the importance of owning CCUS-related infrastructure varies from one firm to another. For example, some firms may wish to have more control over industrial processes and related

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technologies adopted. In this sense, taking ownership of a CO2 capture installation might be influenced by the specific operations of an industrial firm.

Ranking and shortlisting of BM options

Ranking BM options was based on answers to the question: Which of the four CCUS business model options, as identified by Muslemani et al (2020) reflects best the participants' preference? Table 6 provides the ranking of the different CCUS supply chain BM options and summarizes the observations from the participants. As identified in Table 6, the Operator and Vertically Integrated CCUS Business Models received the lowest preference. Joint Venture and Transport CCUS Business Models received the highest preference. Furthermore, the participants suggested a combination of a Joint Venture and Transport CCUS Business Models as having the most adoption potential for CCUS by industrial firms.

Table 6: CCUS supply chain BM options preference by stakeholders

BM options	Preference	Observations by the participants
Joint venture – Transport combination	Preferred Option	• A combination of the JV model and the transport model is preferred. • A Dutch model is a hybrid of JV and Transporter, an example of a JV is the Aramis project.
Joint Venture (JV)	Best Option	• A clear distinction between the Capture and Transport of CO2 (each provided by different parties). • Subsidies go to industrial firms (not to transport and storage) currently, but tailoring to transport and storage would be possible. • SDE++ has a markup for transport and storage costs (only in the Netherlands). • Steel plants would only join for a small percentage
Transport	Second Best Option	• A clear distinction between Capture and Transport of CO2 (each provided by different parties). • Industrial firms are eligible for the SDE++. Although this instrument has a markup for covering transport and storage costs, transport and storage firms are currently not eligible for this instrument. It might be that in the future, transport and storage firms become eligible for the SDE++.

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Operator	Least preferred option	• A clear distinction between the Capture and Transport of CO2 (each provided by different parties) is preferred.
Vertically Integrated	Least preferred option	• Creates a monopoly, and leaves little room for negotiation from emitters. • Questions on whether the vertically integrated model works for European countries, an example is based on China.

Joint Venture and Transport CCUS Business Models

A combination of the JV model and the Transport CCUS BM is preferred. This combination would then be based on a partnership between the industrial firm, and external transport and storage provider firms. The industrial firm is responsible for capturing CO2, and its related equipment and O&M costs. The industrial firm expects to generate revenues from CO2 sales and trading exceeding carbon permits in the market. The industrial company is also liable for the part of capturing CO2 operations. Once CO2 is captured at industrial sites and placed at the gate, transport and storage firms come into the joint venture, as third parties. Transport and storage firms cover costs of transport and storage equipment and their O&M. T&S charge a fixed fee for CO2 transport and storage to industrial firms. Transport and storage firms are responsible and liable for the transportation and/or storage part of the CCUS chain. Regarding utilization, CO2 users cover CO2 purchasing and utilization costs, including O&M. (see discussions in (Muslemani et al., 2020)).

The two preferred BM options relate to the BMI framework in the following way. In terms of Revenue, industrial firms in The Netherlands are eligible for the SDE++ scheme. This Carbon Contract for Difference is one of the main public funding sources in The Netherlands to adopt CCUS. This instrument has a markup for covering transport and storage costs. Yet, transport and storage firms are currently not eligible for this instrument. There are expectations that in the future, transport, and storage firms become eligible for the SDE++ scheme. Moreover, from a market-oriented approach, additional sales of low-carbon commodities are a source of income for firms. Nevertheless, these are foreseen to diminish its present premium value over time. In other words, low-carbon commodities might become mainstream in the future. Therefore, sales of low-carbon commodities in the future might have marginal returns (as additional income, CCS, or CCU costs might be passed on to consumers). Another source pointed out by the stakeholders is the sales of captured CO2 for utilization purposes. However, this is an option perceived as primarily beneficial for chemical industries. Concerning Ownership, a clear distinction between Capture and Transport of CO2 ownership is preferred

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(each one provided by different parties). This comes closely related to Resources in terms of a clear distinction of liabilities from capture, transport, and storage. One of the main concerns of industrial firms is having the guarantee that captured CO2 is collected from industrial sites and transported to permanent storage.

Scenario-Analyses

Phase 1. Baseline analysis of the current situation t_0= *2023* (where are we now?)

From 2022, the Energy Intensive Industry (EII) in The Netherlands and Belgium identifies 5 categories of challenges to adopting CCUS: a) social (acceptance), b) technological (limited options to decarbonize the industry by 2030, and 2050), c) political (a climate agenda to observe by 2030 and 2050 while ensuring local industry competitiveness), d) economic (a lack of revenue schemes/flows in BM aiming at supporting the adoption of CCUS), and e) environmental (to keep global warming below 1.5C by 2030 and to ensure that the EII contributes to such ambition). More in-depth, in 2022, environmental compromises to keep global warming below 1.5C are yet to be supported by available technologies at a commercial level (TRL9 or higher). Nevertheless, there is an industry-oriented perception that CCUS is missing a well-developed carbon market that provides alternatives to a revenue model to existing cost avoidance business models. On the other hand, the way CCS is currently implemented is also perceived as contributing to the revenue/business model as it leads to emission reductions recognized by the ETS. This is true even if CCS today is limited to pipeline transport, for instance. Further CO2 transport (other than CCU) is virtually guaranteed and consensual. Other promising technologies such as Green Hydrogen are yet to further develop before they reach a TRL9. Green H2 applications are promising in the heavy industry. Public and private efforts are in place to further develop hydrogen-based direct reduced iron [DRI] and hydrogen blending in DRI or blast furnaces by 2030.

Carbon Taxes (although limited), and more stringent emissions caps and prices (EU ETS) are assumed to trigger decarbonization, which makes the baseline scenario more interesting. Production costs are becoming higher for the EII and consumers. These challenges and triggers place two major risks to the EII in The Netherlands, Belgium, and Europe. First, it places a risk on the economic competitiveness of local industries by adding a non-level-playing field between production costs in Europe and production costs in foreign economies that do not internalize environmental costs (at least related to the EII). Second, the risk of carbon leakage to jurisdictions with less stringent commitments to climate targets. As a response to anticipate such risks, the EU parliament has recently approved a CBMA. Its main objective is to protect local industries by placing economic adjustments to imports that do not internalize environmental costs. Nevertheless, the recently approved CBAM (provisional agreement) is yet

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to become law and to pass scrutiny by the WTO before it enters into force in 2027, as scheduled. In the short-term future, the CBAM will start its transitional period as of the 1st of October of 2023. This policy instrument sequences to the current 4th phase of the EU ETS[2] which aims at phasing out of free emission rights as of 2026 to reach 0% of free emission rights by 2034 Moreover, the emissions cap will be reduced by a factor of 4.2% per year from 2021 to 2030. The CBAM and the revisions to the EU ETS branch out from the 'Fit for 55 package' which includes further measures and instruments to decarbonize the EII (e.g. Energy taxation, and alternative fuels).

The EII is known for being difficult and expensive to decarbonize. For the EII, some of the main challenges in the innovation, demonstration, and deployment of low-carbon technologies are the lack of funds, revenue streams, and carbon price uncertainty (see the evolution of prices in (ICAP, 2023)). The carbon price has oscillated around 80-90 euros per tonne during 2022 and the first quarter of 2023 (see the evolution of prices in (ICAP, 2023)).

In The Netherlands, the recent expansion of the object of the 'SDE++' aims at supporting the demonstration and scaling-up projects, including CCUS and H2. The SDE++ subsidizes the unprofitable costs of investments in renewable energy technologies or CO2-reducing options. Subsidies are granted for periods of 12 or 15 years (depending on the technology). The SDE++ helps fill the gap between decarbonization technology costs and carbon prices. Therefore, promoting low-carbon competitiveness. Relevant to the EII, the SDE++ aims at supporting the scaling-up/commercialization of CCUS and H2 projects that aim at delivering climate neutrality by 2050.

To add more challenges to the baseline scenario, the Dutch highest court on Wednesday [November 2, 2022] 'ruled that a major carbon capture project might have to be halted because it did not meet European environmental guidelines, dealing a potential blow to construction projects throughout the country. The planned *Porthos* project in the Rotterdam port area would be Europe's largest carbon capture and storage facility, expected to reduce the country's annual CO2 emissions by about 2%.' (Meijer, 2022). Public acceptance is a crucial dimension to consider in the adoption of CCUS by the EII. On a similar note, the social acceptance of CCUS projects has been studied by academic researchers. The main factors identified in how communities respond to CCUS projects depend on the characteristics of projects, the engagement process, risk perceptions (cultural orientations and lifestyles), actions of the stakeholders, characteristics of the community, and the socio-political context. Perceptions of environmental risk are the main concern of society (See reviews on public

[2] See the revisions to the 4th phase of the EU ETS and an update to the trilogies started in July 2022 and the provisional political agreement of 18 December 2022.

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acceptance cases by Oltra et al (2012) and D'Amore et al (2020)). Therefore, offshore CCUS projects receive a more positive perception from society.

The aforementioned covers the main uncertainties that might have an impact on industrial decarbonization towards 2030 and 2050, as identified by the EII in The Netherlands and Belgium. Among the myriad of uncertainties, the guarantee of a competitive European industry and the need for economic incentive schemes to guarantee the industrial decarbonization transition employing CCUS is the main concern among stakeholders in Europe. Table 7, lists the identified Strengths and Weaknesses identified in the baseline scenario.

Table 7: Strengths and Weaknesses of the Baseline Scenario

Strengths	**Weaknesses**
• Decarbonization policy Instruments and pathways are relatively clear (e.g. EU ETS, Carbon Tax) • The CBAM Is approved by the EU Parliament. From October 2023 a transitional phase Is scheduled to start. • Regulating the EU can place a benchmark for other states to level up to gain access to EU markets. The EU is a leader in International Environmental Policy. • Social acceptance for offshore CCUS projects Is more certain than for Inland options. • Public and private ambitions are in place to support the leveling up of the TRL of Green H2 to commercial applications by 2030 (e.g. roadmaps and industrial tests). This could potentially be used in steelmaking (hydrogen-based direct reduced iron [DRI] and hydrogen blending in DRI or blast furnaces).	• TRL of alternatives fuels is low (e.g. H2 is at a TRL 6-7[3]) • TRL of CCUS to commercial levels Is not there yet. Climate ambitions towards 2030 and 2050 are there already. • EII Is hard to decarbonize. • Some carbon cannot be removed or captured. • CBAM could get watered down • Global Warming would at least increase +1.5C. • Decarbonization policy Instruments such as the SDE++ are perceived as insufficient by the EII. The perception of having additional supporting economic instruments prevails. • The applicability of the SDE++ to cover 'foreign' transport and storage providers Is still uncertain. • Limited options to decarbonize the industry by 2030. • Social acceptance Is uncertain.

[3] The different TRLs of Green H2 to power the EII vary accordingly to each specific application (Mature, early applications, demonstration ,or large prototypes).

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• The SDE++ supports the scaling-up/commercialization of CCUS and H2 projects. • Institutional capacity (EU-level).	• The Netherlands' highest court on Wednesday [November 2, 2022] ruled that a major carbon capture project might have to be halted because it did not meet European environmental guidelines (related to including nitrogen emissions), dealing a potential blow to construction projects throughout the country.

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Phase 2. External Scenarios *(t_x=up to 2032)*

Step 1. Identify relevant driving forces (trends)

1a. Driving Forces.

External scenarios aim to reflect social, economic, and technological developments, and other trends together with their driving forces. As a first step, Table 8 categorized the identified relevant external driving forces. To identify of driving forces, we used insights from the *'Report summarising stakeholder analysis to identify key drivers and challenges of the key players (Task 6.3)'* and the work-in-progress paper titled '*Business model framework to the adoption of CCUS in energy-intensive industrial clusters'.*

Table 8: Categorization of the identified relevant external driving forces (trends).

Domain	Category	Indicators (examples)
Social	Social acceptance	Social acceptance (NIMBY), NGOs against storage, elections, etc. Social acceptance for products made from CO2. Political risks as CCS does not have unanimous support in the Dutch parliament – some parties want limited or no CCS deployment. Social discussions about CCS in the Netherlands – the public are not too positive about CCS – they may think that companies don't want to change and that CO2 stored will leak out. A barrier for CCS is public acceptance and whether to use taxpayers' money to support these projects. Several groups in society perceive that CCS is just a way for the fossil industry to maintain current operations. Raises lack of public acceptance of onshore CO2 storage as an example (past negative experience/issues) – offshore North Sea storage has fewer issues, but this involves more cost. Programs where the industry collaborates with academia, technology developers, and research institutes (e.g. TNO). Communication with the public to achieve technology acceptance may be better achieved by parties that are not emitters / have better public relations.
Environmental	Physical Environment	Air, water and soil pollution trends and locations, environmental quality issues (global warming). Climate Change.

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		An actual Carbon leak (at any process).
	Natural resources	Energy prices and availability, raw materials, land use (farming methods, erosion), sustainability (strategic use of resources), and regional distribution of natural resources. Energy availability (hydrogen, electricity) – uncertainties from imports (energy security) and priority of use. Storage capacity for CCS – although uncertain, clarifies that this is unlikely to be an issue. Access to green electricity (in relation to H2 production for CCU). Permitting.
Economical	Macro-economic conditions	Gross domestic product, trade balance, inflation rate, financial markets, changes in national economic structure, regional trading blocks, Competitiveness, CBA.
	Micro-economic conditions	Change in size, type and ownership of firms, labour force structure, changes in economies of scale of key industries. Investment requirement for CCUS – very expensive – and high operational costs. The cost of carbon capture. Customers for low-carbon products are existing customers, mainly those in green industries. Business case is to avoid loss of money (due to carbon price). Need costs to be passed on to customers and to be protected from carbon leakage. Innovation funding to bridge 'valley of death' for technology development. Expect joint venture with specialised companies. Expect full ownership of onsite equipment but not offsite equipment. Business case is to avoid loss of money (due to carbon price). Need costs to be passed to customers and to be protected from competition. Cost effectiveness of CCS – but raises this will be mitigated as ETS cost increases – and lack of supporting subsidy instrument – but raises that the Netherlands SDE++ is quite a supportive mechanism. General need to close the funding gap for projects.
	Market Forces	Demand for a specific quality of iron and steel.

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		A new market for green steel/iron (supply at a competitive price). Fuel prices. ETS prices. Carbon prices
	Impacts of global economy and development	Assistance from multilateral and bilateral agencies, harmonization, risk tolerance and conditions for entry and exit by international firms, stake in local economy by international firms Negotiation of bilateral agreements between capture site and transport & storage companies will take a lot of time.
Political	Geopolitical	Trends in international relations, levels of tensions, conflicts, trade and protectionism Protection from imports using carbon border adjustment. Uncertainty in how fit the carbon border adjustment mechanism will be for European industry. Global positioning and what happens in other global regions, as carbon pricing in European is perceived as more stringent than in other regions in the world and this is seen as a threat for European industry. Governments within the EU cannot agree on preferred decarbonisation strategy (e.g. carbon capture versus hydrogen).
	National	Change in governmental development strategy and policy, changes in legislation, changes in structure and responsibility of ministries, changes in rules governing formation and functioning of parties, governmental stability, likelihood of change/overthrow. Support from policy to mitigate the cost barrier – highlighting contract for difference (such as SDE++). Policies that create markets for CO2-derived chemicals or fuels. Regulations could create a market for CO2-derived products (e.g. similar to gasoline blending for bioethanol). Mitigating cross-chain risk - governments could provide an exemption of ETS for emitters that have invested in carbon capture technology but where T&S is not available as expected. State should support via providing guarantees, as private companies will not be able to take up the full risks – currently not aware of this being proposed by government.

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		Regulations - market creation for CCU products via obligation. Government is currently assisting development of CO2 transport and storage through an accelerated permitting process. In future, there could be additional policy interventions but no decisions have been made. CCU is not as far developed as CCS – the commercial process needs to be developed – so support is different. It is not SDE++ mechanism, instead funding is available for development (several funding programs in Netherlands). Political risks as CCS does not have unanimous support in Dutch parliament – some parties want limited or no CCS deployment. Stability of regulations (impact of elections on support / targets) – raising long project lifetimes and need for stable framework. Governments within the EU cannot agree on preferred decarbonisation strategy (e.g. carbon capture versus hydrogen). Legislative framework to enable investment decisions may be preferable to funding programs. Certification to distinguish low-carbon products could allow premium or separate market - customers will pay a premium if availability is scarce. CO2 sequestration liability. Stability of regulations (impact of elections on support / targets) – raising long project lifetimes and need for stable framework. For shipping, the liabilities remain with the capture installation because ships cannot currently hold an ETS permit (temporary solution, expect ships to be included in ETS in future).
Technological	Infrastructure	Level of technology in key industries, emerging technologies, capacity to manufacture technology for export. The availability and (small) scale of technologies. Competition for CO2 storage and fair use of CO2 storage capacity. CO2 sequestration liability. Technology in terms of economic feasibility and regulation that goes with it, although raises this is a smaller issue as some capture technologies (e.g. amines) are more developed.

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		OWNERSHIP: Expect full ownership of onsite equipment but not offsite equipment. Offsite equipment can be initial joint venture with then divestment once technologies mature. Emitter expects CO2 leakage to be responsibility of storage companies with some shared liability with government – similar to Oil & Gas liabilities. Parties should only have liability for the risks that they control. Where to split the CCUS chain is a balance of risks and guarantees. Speed of development of transport and storage infrastructure. CCS projects have a lifetime of 15 years, but it is uncertain whether companies will continue emitting CO2 for the next 15 years – main source of CO2 currently is from natural gas, but could move towards importing hydrogen (mentions green ammonia).
	Future directions	Basic research and technical education trends, digital divide, computer and telecom infrastructure and trends, potential for rapid diffusion of new technologies from abroad. Innovation funding to bridge 'valley of death' for technology development. Advantage to keeping options open with regards to decarbonisation of industry, with decarbonisation plans exploring a variety of options initially. Alternative renewable energy sources Decarbonization alternatives (e.g. massive RET deployment and hydrogen). Blue Hydrogen production.

1b. Impact-uncertainty Matrix

Table 8 shows the baseline analysis with the identified several driving forces. To arrive at short-listing drivers, we employed an impact-uncertainty matrix (see Table 9). We categorized the different driving forces by their degree of impact and uncertainty. The most uncertain and impactful driving forces became critical scenario drivers to elaborate further on the external scenarios in Step 2. Participants in the second round of the Delphi method validated the driving forces with the highest degrees of uncertainty and impact.

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Table 9: Impact-Uncertainty Matrix. Note: green shaded cells indicate key focus areas.

Degree of Impact/ Degree of uncertainty	Low Uncertainty	Medium Uncertainty	High Uncertainty
High Impact	**Critical planning issues** Avoiding purchasing allowances for CO2. Need costs to be passed to customers and to be protected from competition. Investment requirement for CCUS – very expensive – and high operational costs. Public willingness to pay a price premium differs per country. Business model for transport is still under-development. Increasing CO2 price (levy) and SDE++ subsidy mechanism. Expects OPEX costs for decarbonisation projects to be large in comparison to CAPEX and therefore need for operational subsidies such as contract for difference. Contract for difference could be very expensive for governments so need to select projects wisely such that the business model shifts to give governments interest.	**Important scenario drivers** Policy Support for CCU. The CCS transitional Nature. Air, water and soil pollution trends and locations, environmental quality issues (global warming). An actual Carbon leak (at any process). Access to green electricity (in relation to H2 production for CCU). Energy availability (hydrogen, electricity) – uncertainties from imports (energy security) and priority of use. Cross-border regulations – lack of regulation regarding the transportation of CO2 cross-border in Europe is a burden. This restricts emitters to activities in the Netherlands for storage, when other countries such as the UK and Norway are making progress. If it weren't for border issues[4], the pace of CCS roll-out would be increased.	**Critical scenario drivers.** Revenue model. Financing (is the SDE++ enough and durable?). Ownership. Liabilities. CBAM. Competition. Carbon Leakage risk. Transport and Storage Capacity Economics – need a business case with positive return to execute. Mitigating cross-chain risk - governments could provide an exemption of ETS for emitters that have invested in carbon capture technology but where T&S is not available as expected. (e.g. contracts for commercialization with no obligation of return from private to public). State should support via providing guarantees, as private companies will not be able to take up the full risks – currently not aware of this being proposed by government. Future price uncertainty for CO2 derived synthetic fuels. Fuel prices. ETS prices.

[4] Within and outside the European Economic Area.

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	Gross domestic product, trade balance, inflation rate, financial markets, changes in national economic structure, regional trading blocks, Competitiveness, CBA.	Cost effectiveness of CCS – but raises this will be mitigated as ETS cost increases – and lack of supporting subsidy instrument – but raises that the Netherlands SDE++ is quite a supportive mechanism. General need to close the funding gap for projects. Programs where industry collaborates with academia, technology developers and research institutes (e.g. TNO). Industry wants a level playing field (within an industry) and policy can help with this. Level playing field would promote ETS. CAPEX & OPEX Cost. Cross-party risk management and division of liabilities. Uncertainty about future regulations related to carbon leakage (impact of Carbon Border Adjustment Mechanism), cross-border transport of CO2, and liability between different stakeholders across the CCS/CCU value chain.	Climate Change Speed of development of alternative fuels (uncertainty for refineries). Political risks as CCS does not have unanimous support in Dutch parliament – some parties want limited or no CCS deployment. Barrier for CCS is public acceptance and whether to use taxpayers' money to support these projects. Several groups in society perceive that CCS is just a way for the fossil industry to maintain current operations. Public acceptance. Social acceptance (NIMBY), NGO's against storage, elections, etc. Uncertainty in how fit the carbon border adjustment mechanism will be for European industry. Global positioning and what happens in other global regions, as carbon pricing is. only [mainly] a European thing and might be a threat for European industry. Decarbonization alternatives (e.g. massive RET deployment and hydrogen). Blue Hydrogen production.
Medium	**Important planning issues** Regulations could create a market for CO2-derived products (e.g. similar to gasoline blending for bioethanol).	**Important planning issues** Emitter expects CO2 leakage to be responsibility of storage companies with some shared liability with	**Important scenario drivers** Governments within the EU cannot agree on preferred decarbonisation strategy (e.g. carbon capture versus hydrogen).

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Impact	Several groups in society perceive that CCS is just a way for the fossil industry to maintain current operations. Customers for low-carbon products are existing customers, mainly those in green industries. Need costs to be passed to customers and to be protected from competition.	government – similar to Oil&Gas liabilities. Parties should only have liability for the risks that they control. Where to split the CCUS chain is a balance of risks and guarantees. Negotiation of bilateral agreements between capture site and transport & storage companies will take a lot of time.	Demand for a specific quality of iron and steel. A new market for green-steel/iron (supply at a competitive price). Expect full ownership of onsite equipment but not offsite equipment. Offsite equipment can be initial joint venture with then divestment once technologies mature.
Low Impact	**Monitorable issues** Business case is to avoid loss of money (due to carbon price). Need costs to be passed to customers and to be protected from competition. Offshore North Sea storage has fewer public acceptance issues, but this involves more cost. Storage capacity for CCS – although uncertain, clarifies that this is unlikely to be an issue. Permitting.	**Monitorable issues** Basic research and technical education trends, digital divide, computer and telecom infrastructure and trends, potential for rapid diffusion of new technologies from abroad.	**Issues to monitor and reassess impacts** Advantage to keeping options open with regards to decarbonisation of industry, with decarbonisation plans exploring a variety of options initially. Alternative renewable energy sources [additional to the existing sources].

Note: green shaded cells indicate key focus areas

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Step 2. External-scenarios frame

2a. Critical Scenario Drivers

To arrive at the selection of critical scenario drivers, the two most uncertain and impactful drivers were selected based on input from the stakeholders in the focus groups. Out of these two critical scenario drivers two axes with four quadrants branched out (see Scenario Matrix in Table 9). If a larger number of forces clusters in the upper right corner, the aim is to select two factors that are considered the most important. These will be used to set up a scenario matrix with the selected factors as axes (see Table 10).

Table 10: Critical scenario driver

	High Uncertainty
High Impact	• Critical scenario drivers. • Revenue model. • Financing (is the SDE++ enough and durable?). • Ownership. • Liabilities. • CBAM. • Competition. • Carbon Leakage. • Transport and Storage Capacity. • Economics – need a business case with positive return to execute. • Mitigating cross-chain risk - governments could provide an exemption of ETS for emitters that have invested in carbon capture technology but where T&S is not available as expected. (e.g. contracts for commercialization with no obligation of return from private to public). • State should support via providing guarantees, as private companies will not be able to take up the full risks – currently not aware of this being proposed by government. • Future price uncertainty for CO2 derived synthetic fuels. • Fuel prices. • ETS prices. • Climate Change. • Speed of development of alternative fuels (uncertainty for refineries). • Political risks as CCS does not have unanimous support in Dutch parliament – some parties want limited or no CCS deployment.

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	• Barrier for CCS is public acceptance and whether to use taxpayers' money to support these projects. Several groups in society perceive that CCS is just a way for the fossil industry to maintain current operations. • Public acceptance. Social acceptance (NIMBY), NGO's against storage, elections, etc. • Uncertainty in how fit the carbon border adjustment mechanism will be for European industry. • Global positioning and what happens in other global regions, as carbon pricing is. only [mainly] a European thing and might be a threat for European industry. • Decarbonization alternatives (e.g. massive RET deployment and hydrogen). • Blue Hydrogen production.

The 2 Axes are:

1. **Funding Schemes (x).**
   - (positive) Economic incentives help create a revenue model to support decarbonization.
   - (negative) Missing incentives, business as usual.
2. **Competitiveness protection (y).**
   - (positive) Strong European industry with well-supportive economic incentives and an effective regulatory mechanism (including CBAM).
   - (negative) Carbon leakage and competition loss.

2b. Developing scenarios.

The following four subheadings describe each quadrant of the two axes selected. As illustrated in Table 11, each quadrant provides the narrative of each external scenario. Data from other important driving forces (quadrants) is also used to inform the making of scenarios (see Table 11).

Table 21: Input data for the external scenarios narratives.

Impact/ Uncertainty	Low Uncertainty	Medium Uncertainty	High Uncertainty
Medium Impact	**Important planning issues** Regulations could create a market for CO2-derived products (e.g. similar to gasoline blending for bioethanol).	**Important planning issues** Emitter expects CO2 leakage to be responsibility of storage companies with some	**Important scenario drivers** Governments within the EU cannot agree on preferred decarbonisation strategy (e.g. carbon capture versus hydrogen).

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	Several groups in society perceive that CCS is just a way for the fossil industry to maintain current operations. Customers for low-carbon products are existing customers, mainly those in green industries. Need costs to be passed to customers and to be protected from competition.	shared liability with government – similar to Oil&Gas liabilities. Parties should only have liability for the risks that they control. Where to split the CCUS chain is a balance of risks and guarantees. Negotiation of bilateral agreements between capture site and transport & storage companies will take a lot of time.	Demand for a specific quality of iron and steel. A new market for green-steel/iron (supply at a competitive price). Expect full ownership of onsite equipment but not offsite equipment. Offsite equipment can be initial joint venture with then divestment once technologies mature. Climate Change.
Low Impact	**Monitorable issues** Business case is to avoid loss of money (due to carbon price). Need costs to be passed to customers and to be protected from competition. Offshore North Sea storage has fewer public acceptance issues, but this involves more cost. Storage capacity for CCS – although uncertain, clarifies that this is unlikely to be an issue. Permitting.	**Monitorable issues** Basic research and technical education trends, digital divide, computer and telecom infrastructure and trends, potential for rapid diffusion of new technologies from abroad.	**Issues to monitor and reassess impacts** Advantage to keeping options open with regards to decarbonisation of industry, with decarbonisation plans exploring a variety of options initially. Alternative renewable energy sources [additional to the existing sources].

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1. *Less Economic Incentives and More European Competitiveness Protection (-/+)*

By 2032, the EII in The Netherlands and Belgium **partially adopted CCUS**. In the last ten years, the EII faced 5 challenges adopting CCUS: a) social acceptance, b) slow development of technological innovations (limited options to decarbonize the industry), c) political (local industry competitiveness), d) economic (a lack of revenue schemes/flows in BM aiming at supporting the adoption of CCUS), and e) environmental (to keep global warming below 1.5C by 2050 and to ensure that the EII contributes to such ambition).

In 2032, we live in a context in which society struggled to reach environmental compromises to keep global warming below 1.5C (compared to 1990). In part, the TRL of CCUS and green H2 on the different applications relevant to the EII took longer than expected to reach a commercial level (TRL9 or higher). This event has had implications to address the magnitude of the environmental compromises as adopted in the last decade to achieve a median CO2 abated by CCS of 230-430 MtCO2/year in 2030. On a similar note, the EU did not reach its ambitious target of having 20 million mt/year[5] of available green hydrogen from 2030. Nevertheless, public and private efforts have resulted in a well-developed carbon market for CCU that provides additional revenue to existing business models. Nevertheless, during the 2020s the premium from sales of low-carbon commodities has stabilized (marginal revenue).

Carbon Taxes (although limited to ETS sectors) and a more stringent EU ETS are pressing in 2032 to further decarbonize the EII. Although production and consumption costs become higher in the 2020s for the EII and passed on to consumers, the Social Climate Fund has observed a just transition during the last decade. During the last decade, the sectors covered by the EU ETS did not reduce emissions by 43% (compared to 2005 levels). The system of free allocation was prolonged until 2030 trying to protect sectors at the highest risk of relocating their production outside of the EU. These sectors received 100% of their allocation for free. For less exposed sectors, free allocation phased out in 2027 from a maximum of 30% to 0 at the end of the EU ETS Phase 4 in 2030. (A considerable number of free allowances were also set aside for new and growing installations).

The EU managed to intentionally influence a predictable and stable carbon price in the last decade. From 2030, the carbon price is €100 per tonne (as forecasted in the last decade[6]). The imposed CO2 tax works in a baseline-and-credit system and emissions above the baseline have been effectively taxed. To help finance the gap between CO2 abatement costs and CO2 price within the EU ETS, CCfDs played a major role in financing the additional abetment costs for the EII in the last decade. Against the concerns of the EII, CCUS is not a transitional technology but a key element of a set of decarbonization technologies (e.g. RET, large

[5] Of which 10mt renewable (non-green) H2 production and 10mt of renewable H2 imports.
[6] [See forecasts in (PricewaterhouseCoopers, 2022; Simon, 2021)]

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deployment of Electric Arc Furnaces, and H2). Nevertheless, as the EII anticipated decarbonization costs have been higher than expected. Additional costs came at the cost of the EII and were passed on to customers. The SDE++ has been the major economic incentive received by the EII to support decarbonization. The scheme did not anticipate additional costs nor accounted for them. Nevertheless, the EII received free allowances until 2030 as anticipated.

A major turning point for the local industry in Europe in 2032 is the approval of the CBAM by the WTO and the phasing out of free allowances from 2030. The CBAM entered into force in 2027 right after its transitional period. The EII experiences an improved level-playing field between domestic and imported goods allowing carbon pricing to trigger the industrial transition. There is no evidence of carbon leakage yet showing the relocation of the European EII to other jurisdictions with less stringent climate targets. Evidence supporting the direct link between the CBMA and emissions abatement worldwide is divided.

The CBAM set an incentive for third countries to put in place carbon pricing to avoid disadvantages for their exporting industry. As a result, some non-European economies have internalized environmental costs into their industrial processes as a strategy to enter the European market of energy-intensive commodities (e.g. iron and steel). For example, economies such as India, Brazil, Indonesia, and South Africa have adopted domestic carbon pricing models. However, the CBAM has already gained a reputation as a 'green protectionism' policy instrument. Other economies have delayed their decarbonization ambitions and started competing with other less stringent economies. What is certain is that the CBAM contributed to supporting limiting global warming by 1.5 degrees – in Europe and worldwide. Consequently, these events have largely contributed to a carbon-price incentive for cleaner production.

As a response, the EII adopted a business approach to finance the industrial decarbonization compromises. A Joint Venture-Transport CCUS BM showed to be an effective partnership to delineate ownership, liability, and cost-sharing. With this business model, the EII deployed carbon capture technologies at industrial sites and limited its ownership, management, and liability within the gates of each industrial site (liability is not shared in a Public-Private Agreement). European Transport and Storage firms have provided finance, expertise, assets, and liability to provide enough, seamless, and expedited transport and permanent storage of CO2. With regard to revenues, the SDE++ has partially financed for the EII to cover its OPEX. Revenue from sales of CO2 utilization and low-carbon commodities benefited from a premium in the last decade. However, revenue in these regards is marginal in 2032. As a response, supporting regulation is under discussion as a measure to create a market for CO2-derived products and to establish a floor quota for steel and iron production (e.g. similar to gasoline blending for bioethanol).

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In 2032, CCUS is socially accepted. Permanent storage offshore has been a welcome option. During the last decade, NGOs pushed for not accepting CO2 storage inland.

2. More Economic Incentives and More Competitiveness Protection (+/+)

In 2032, the EII in The Netherlands and Belgium **successfully** adopted CCUS. In the last ten years, the EII successfully addressed 5 challenges adopting CCUS: a) social acceptance, b) slow development of technological innovations (limited options to decarbonize the industry), c) political (local industry competitiveness), d) economic (a lack of revenue schemes/flows in BM aiming at supporting the adoption of CCUS), and e) environmental (to keep global warming below 1.5C by 2050 and to ensure that the EII contributes to such ambition).

In 2032, we live in a context in which society reached environmental compromises to keep global warming below 1.5C (compared to 1990). In part, the TRL of CCUS and green H2 came to commercial viability by the end of the 2030s. This event has had implications to address the magnitude of the environmental compromises as adopted in the last decade to achieve a median CO2 abated by CCS of 230-430 MtCO2/year in 2030. On a similar note, the EU did reach its ambitious target of having 20 million mt/year[7] of available green hydrogen from 2030. Nevertheless, public and private efforts have resulted in a well-developed carbon market for CCU that provides additional revenue to existing business models. Nevertheless, during the 2020s the premium from sales of low-carbon commodities has stabilized (marginal revenue).

Carbon Taxes and a more stringent EU ETS are pressing in 2032 to further decarbonize the EII. Although production and consumption costs become higher in the 2020s for the EII and passed on to customers, the Social Climate Fund has observed a just transition during the last decade. During the last decade, the sectors covered by the EU ETS reduced emissions by 43% (compared to 2005 levels). The system of free allocation trying to protect the industrial sector, which is at a high risk of relocating their production outside of the EU, ended in 2033[8]. The EII sectors received 100% of their allocation for free until 2030. For less exposed sectors, free allocation phased out in 2027 from a maximum of 30% to 0 at the end of the EU ETS Phase 4 in 2030. (A considerable number of free allowances were also set aside for new and growing installations).

[7] Of which 10mt renewable (non-green) H2 production and 10mt of renewable H2 imports.
[8] See the revisions to the 4th phase of the EU ETS and an update to the trilogies started in July 2022 and the provisional political agreement of 18 December 2022.

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The EU managed to intentionally influence a predictable and stable carbon price in the last decade. From 2030, the carbon price reached €100 per tonne (according to the EU ETS forecast[9]). The imposition of a CO2 tax has worked as a baseline-and-credit system and emissions above the baseline have been effectively taxed. To help finance the gap between CO2 abatement costs and CO2 price within the EU ETS, CCfDs played a major role in financing the additional abetment costs for the EII in the last decade. Against the concerns of the EII, CCUS is not a transitional technology but a key element of a set of decarbonization technologies (e.g. RET, large deployment of Electric Arc Furnaces, and H2). As the EII anticipated, decarbonization costs have been higher than expected. Additional costs to industrial decarbonization came at the cost of a revision and adjustment to the SDE++ and State Aid. Therefore, additional costs did not come at the cost of the EII and were not passed on to customers. The SDE++ has been the major economic incentive received by the EII to support decarbonization.

A major turning point for the local industry in Europe in 2032 is the approval of the CBAM by the WTO and the phasing out of free allowances from 2030. The CBAM entered into force in 2027 right after its transitional period. The EII experiences an improved level-playing field between domestic and imported goods allowing carbon pricing to trigger the industrial transition. There is no evidence of carbon leakage yet showing the relocation of the European EII to other jurisdictions with less stringent climate targets. Evidence supporting the direct link between the CBMA and emissions abatement worldwide is divided.

The CBAM set an incentive for third countries to put in place carbon pricing regimes to avoid disadvantages for their exporting industry. As a result, some non-European economies have internalized environmental costs into their industrial processes as a strategy to enter the European market of energy-intensive commodities (e.g. iron and steel). For example, economies such as India, Brazil, Indonesia, and South Africa have adopted domestic carbon pricing models. However, the CBAM has already gained a reputation as a 'green protectionism' mechanism. Other economies have delayed their decarbonization ambitions and started competing with other less stringent economies. What is certain is that the CBAM contributed to supporting limiting global warming by 1.5 degrees – in Europe and worldwide. Consequently, these events have largely contributed to a carbon-price incentive for cleaner production.

As a response, the EII adopted a business approach to finance the industrial decarbonization compromises. A Joint Venture-Transport CCUS BM showed to be an effective partnership to delineate ownership, liability, and cost-sharing. With this business model, the EII deployed carbon capture technologies at industrial sites and limited their ownership, management, and liability within the gates of each industrial site (liability is not shared in a Public-Private Agreement). European Transport and Storage firms have provided finance, expertise, assets,

[9] [See forecasts in (PricewaterhouseCoopers, 2022; Simon, 2021)]

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and liability to provide enough, seamless, and expedited transport and permanent storage of CO2. Regarding revenue, the SDE++ has financed each specific process of capturing, transporting, and storage. Revenue from sales of CO2 utilization and low-carbon commodities benefited from a premium in the last decade. As a response, supporting regulation is under discussion as a measure to create a market for CO2-derived products and to establish a floor quota for steel and iron production (e.g. similar to gasoline blending for bioethanol).

In 2032, CCUS is socially accepted. Permanent storage offshore has been a welcome option. During the last decade, NGOs pushed for not accepting CO2 storage inland.

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3. Less Economic Incentives and Less Competitiveness Protection (-/-)

In 2032, the EII in The Netherlands and Belgium **partially** adopted CCUS. In the last ten years, the EII faced 5 challenges adopting CCUS: a) social acceptance, b) slow development of technological innovations (limited options to decarbonize the industry), c) political (local industry competitiveness), d) economic (a lack of revenue schemes/flows in BM aiming at supporting the adoption of CCUS), and e) environmental (to keep global warming below 1.5C by 2050 and to ensure that the EII contributes to such ambition).

In 2032, we live in a context in which society struggled to reach environmental compromises to keep global warming below 1.5C (compared to 1990). In part, the TRL of the different applications of CCUS and green H2, and relevant for the EII, took longer than expected to reach a commercial level (TRL9 or higher). This event has had implications to address the magnitude of the environmental compromises as adopted in the last decade to achieve a median CO2 abated by CCS of 230-430 MtCO2/year in 2030. On a similar note, the EU did not reach its ambitious target of having 20 million mt/year[10] of available green hydrogen from 2030. Nevertheless, private efforts have resulted in a carbon market for CCU that provides additional revenue to existing business models. Nevertheless, during the 2020s the premium from sales of low-carbon commodities has stabilized (marginal revenue).

Carbon Taxes and a more stringent EU ETS are pressing in 2032 to further decarbonize the EII. Although production and consumption costs become higher in the 2020s for the EII and passed on to customers, the Social Climate Fund has observed a just transition during the last decade. During the last decade, the sectors covered by the EU ETS did not reduce emissions by 43% (compared to 2005 levels). The system of free allocation was prolonged after 2030, even until 2033, trying to protect sectors at the highest risk of relocating their production outside of the EU[11]. These sectors received 100% of their allocation for free. For less exposed sectors, free allocation phased out in 2027 from a maximum of 30% to 0 at the end of the EU ETS Phase 4 in 2030. (A considerable number of free allowances were also set aside for new and growing installations).

The EU did not manage to intentionally influence a predictable and stable carbon price in the last decade. From 2030, the carbon price fluctuated around €100 per tonne. Nevertheless, the imposition of a CO2 tax works in a baseline-and-credit system, and emissions above the baseline have been effectively taxed. To help finance the gap between CO2 abatement costs and CO2 price within the EU ETS, CCfDs played a major role in financing some of the additional abetment costs for the EII in the last decade. Against the concerns of the EII, CCUS is not a transitional technology but a key element of a set of decarbonization technologies (e.g. RET,

[10] Of which 10mt renewable (non-green) H2 production and 10mt of renewable H2 imports.

[11] See the revisions to the 4th phase of the EU ETS and an update to the trilogies started in July 2022 and the provisional political agreement of 18 December 2022.

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large deployment of Electric Arc Furnaces, and H2). Nevertheless, as the EII anticipated decarbonization costs have been higher than expected. Additional costs came at the cost of the EII and were passed on to customers. The SDE++ has been the major economic incentive received by the EII to support decarbonization. The scheme did not anticipate additional costs nor accounted for them.

What impacts the local industry in Europe in 2032 is the water down of the CBAM by the WTO which failed to enter into force in 2027 and the phasing out of free allowances from 2030. The EII experiences a non-level-playing field between production costs in Europe and production costs in foreign economies that have not internalized environmental costs yet or that took longer than Europe. Moreover, after 2030 the granting of free allowances became phased out. Evidence finds it difficult to prove that the relocation of the European EII to other jurisdictions with less stringent climate targets was driven by carbon leakage. This has come with environmental implications supporting the failure to limit global warming by 1.5 degrees - worldwide. The EU decided not to prolong the granting of free emissions allowances (EU ETS) to the EII beyond 2030. Consequently, these events have largely muted the carbon-price incentive for cleaner production.

As a response, the EII adopted a business approach to finance the industrial decarbonization compromises. A Joint Venture-Transport CCUS BM showed to be the only option for industrial firms to delineate ownership, liability, and cost-sharing with transport and storage firms. With this business model, the EII deployed carbon capture technologies at industrial sites and limited their ownership, management, and liability within the gates of each industrial site (liability is not shared in a Public-Private Agreement). Especially, considering the limited economic competitiveness protection the EII received over the last decade. European Transport and Storage firms have provided finance, expertise, assets, and liability to provide enough, seamless, and expedited transport and permanent storage of CO2. The SDE++ has partially financed each specific process of capturing, transporting, and storage. Revenue from sales of CO2 utilization and low-carbon commodities benefited from a premium in the last decade. However, revenue in these regards is marginal in 2032. As a response, supporting regulation is under discussion as a measure to create a market for CO2-derived products and to establish a floor quota for steel and iron production (e.g. similar to gasoline blending for bioethanol).

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3. *More Economic Incentives and Less Competitiveness Protection. (+/-)*

In 2032, the EII in The Netherlands and Belgium **partially adopted CCUS**. In the last ten years, the EII faced 5 challenges adopting CCUS: a) social acceptance, b) slow development of technological innovations (limited options to decarbonize the industry), c) political (local industry competitiveness), d) economic (a lack of revenue schemes/flows in BM aiming at supporting the adoption of CCUS), and e) environmental (to keep global warming below 1.5C by 2050 and to ensure that the EII contributes to such ambition).

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Carbon Taxes (although limited) and a more stringent EU ETS are pressing in 2032 to further decarbonize the EII. Production and consumption costs become higher in the 2020s for the EII and consumers. During the last decade, the sectors covered by the EU ETS reduced emissions by 43% (compared to 2005 levels). The system of free allocation trying to protect sectors at the highest risk of relocating their production outside of the EU ended in 2030, as scheduled. These sectors received 100% of their allocation for free until 2030. For less exposed sectors, free allocation phased out in 2027 from a maximum of 30% to 0 at the end of the EU ETS Phase 4 in 2030. (A considerable number of free allowances were also set aside for new and growing installations).

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[12] Of which 10mt renewable (non-green) H2 production and 10mt of renewable H2 imports.
[13] [See forecasts in (PricewaterhouseCoopers, 2022; Simon, 2021)]

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a revision and adjustment to the SDE++. Therefore, additional costs did not come at the cost of the EII and were not passed on to consumers. The SDE++ has been the major economic incentive received by the EII to support decarbonization.

What impacts the local industry in Europe in 2032 is the water down of the CBAM by the WTO which failed to enter into force in 2027 and the phasing out of free allowances from 2030. The EII experiences a non-level-playing field between production costs in Europe and production costs in foreign economies that have not internalized environmental costs yet or that took longer than Europe. Moreover, after 2030 the granting of free allowances became phased out. Some evidence of carbon leakage shows the relocation of the European EII to other jurisdictions with less stringent climate targets. This has come with environmental implications to limit global warming by 1.5 degrees -worldwide. The EU decided not to prolong the granting of free emissions allowances (EU ETS) to the EII beyond 2030. Consequently, these events have largely muted the carbon-price incentive for cleaner production.

As a response, the EII adopted a business approach to finance the industrial decarbonization compromises. A Joint Venture-Transport CCUS BM showed to be an effective partnership to delineate ownership, liability, and cost-sharing. With this business model, the EII deployed carbon capture technologies at industrial sites and limited their ownership, management, and liability within the gates of each industrial site (liability is not shared in a Public-Private Agreement). Especially, considering the limited economic competitiveness protection the EII received over the last decade. European Transport and Storage firms have provided finance, expertise, assets, and liability to provide enough, seamless, and expedited transport and permanent storage of CO2. Regarding revenue, the SDE++ has sourced the finance for each specific process of capturing, transporting, and storage. Revenue from sales of CO2 utilization and low-carbon commodities benefited from a premium in the last decade. No supporting regulations are in place yet to create a market for CO2-derived products (e.g. similar to gasoline blending for bioethanol).

In 2032, CCUS is socially accepted. Permanent storage offshore has been a welcome option. During the last decade, NGOs pushed for not accepting CO2 storage inland.

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Table 32: List of Opportunities and Threats identified in the 4 External Scenarios (considering stakeholders' input as introduced in Section 4).

Opportunities	Threats

• The chemical industry will benefit more compared to steel. The policy is currently quite fluid.
• EU policy is enforcing hydrogen technology, so less need for CCS/CCU.
• Changing mindsets in the EU are needed (e.g. impacts such as energy blackouts changing mindsets).
• Socially speaking, the public will not have a say in economic development, but conventional steel-making (blast furnaces) will disappear over a certain time in Europe. More EAF will appear using renewables/nuclear.
• Expect the first users of CCS to be the chemical industry as already have relationships with O&G companies and can't avoid CO2
• The policy is quite fluid and is changing, perhaps H2 is too expensive for the near term.
• The carbon market and the need for CO2 for synthetic fuels will determine the balance for CCS/CCU
• The above also depends on the cost of energy as need energy for CCU
• The CBAM entering into force. The creation and regulation of a minimum quota on low-carbon or CO2-derived commodities. Levelling-up production costs between European and non-
	• The general public has no say in econ. Development (Steelmaking conventional technology will disappear in the EU, moving to electric furnaces and scrap technology. Also, alternative technologies will appear in different continents, similar to the aluminum industry.) The cost of energy is decisive.
	• 2032 is not far away for CCS; the first commercial projects operating; pipelines up and running and use of the depleted gas field. Cross-border CCS projects. Fulfilling its promises.
	• First developments in the USA: inflation reduction act[14].
	• Hydrogen technology might not suffice
	• Impact on BM:
	  • The carbon market and price and need for CO2 determine the balance for CCS/CCU (comes from the same capture unit) and the willingness of customers to pay.
	  • Depends on the cost of energy vs emissions from the process (not all to convert to hydrogen technology).
	• EU policy is mainly about using H2 for green steel so no need for CCUS.
	• The cost of energy determines everything.
	• Maybe the EU will apply more policies, but unsure how quickly that will come
	• CBMA. Criticisms of Green Protectionism
	• The uncertain and dynamic gap between abatement costs and the (certain) CO2 price within the EU ETS.
	• Extending the durability and budget of the SDE++ policy instrument in case necessary is uncertain.
	• Implies to regulate and incentivize the circular economy approaches, beyond the EII.

[14] The EU's reaction is pending. See objective of the UN Net-Zero Insurance Alliance.

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European markets by Internalizing environmental costs related to the EII. • Avoiding competition loss, implies having the effects of the Social Climate Fund received. In this sense passing on additional production costs to consumers is compensated. • Avoiding carbon leakage implies having the CBAM in place to protect the increasing production costs from the European EII as compared to non-European EII. • Having a clear allocation of risks between each process of capture, transport, and storage • Transport and Storage of CO2 became mainstream. There is a market for transport and storage. There are Transport and Storage options for different CO2 qualities from the EII. • Regulation regarding the cross-border transportation of CO2 in Europe is in place.	• Decarbonization costs are partially covered by the SDE++ scheme and additional costs are passed to consumers. • It is impacted by not filling the uncertain and dynamic gap between abatement costs and the (certain) CO2 price within the EU ETS. • Decarbonization costs are partially covered by the SDE++ scheme and additional costs are passed to consumers. • Not extending the durability and budget of the SDE++ policy instrument in case necessary. • Industrial decarbonization might increase production costs that might be passed on to consumers. • In the case that CCUS is a transitional technology with a timeframe of 15 years, this would require additional investments to adopt the next decarbonization technology. The EII sees this trend as a risk that might lead to carbon leakage. To avoid this perception, the SDE++ should anticipate this possibility by giving certainty of future access to the same policy instrument to other related technologies that we as a society might transition towards or to related technologies that the EII might need (e.g. H2). • H2 is not at a commercial level yet. Energy prices are still a burden for CCUS. Additional costs of production are passed on to consumers. • Regulation regarding the cross-border transportation of CO2 in Europe is NOT in place. • Climate Change has impacted society-wide as expected under a scenario of global warming below 1.5C. • It implied that NGOs and society at wide accept that every solution to mitigate the adverse effects of climate change counts (No perfect solution). • Supporting local economies (European EII is used as an ideology to create intersubjective meaning between the different sectors of society).

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Less Economic Incentives and More Competitiveness Protection (-/+)

Table 43: List of impacts of Scenario 1.

Category	Trends	Potential impacts of trends
Economical	Financing (durability of SDE++ extended beyond 15 years).	It is impacted by not filling the uncertain and dynamic gap between abatement costs and the (certain) CO2 price within the EU ETS. Decarbonization costs are partially covered by the SDE++ scheme and additional costs are passed to consumers. Not extending the durability and budget of the SDE++ policy instrument in case necessary.
	CBAM is in place	Criticisms of Green Protectionism
	Regulations did create a market for CO2-derived products	A minimum quota on low-carbon or CO2-derived commodities is in place. It further implies that the CBAM enters into force. Implies to regulate and incentivize the circular economy approaches, beyond the EII.
Political	Carbon Taxes and price of allowances increase	This is reflected in an increase in production and consumer costs. Avoid competition loss, implies having the effects of the Social Climate Fund received. In this sense passing on additional production costs to consumers is compensated. Avoiding carbon leakage implies having the CBAM in place to protect the increasing production costs from the European EII as compared to non-European EII.
	Future prices of CO2 do become certain	This implies having a Carbon Tax in Europe, the 4th Phase of EU ETS as planned, and the entering of CBAM into force.
	Liability is not shared in a Public-Private arrangement	It implies having a clear allocation of risks between each process of capture, transport, and storage.

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Technological	Transitional tech (15y with 6y time to put projects to run).	In the case that CCUS is a transitional technology with a timeframe of 15 years, this would require additional investments to adopt the next decarbonization technology. The EII sees this trend as a risk that might lead to carbon leakage. If the SDE++ does not anticipate this possibility by giving certainty of future access to the same policy instrument to other related technologies that we as a society might transition towards, another policy instrument should fill this gap (e.g. other subsidies to finance H2 projects).
	Transport and Storage Capacity is enough, 'quasi' affordable, and seamless.	Transport and Storage of CO2 became mainstream. There is a market for transport and storage. There are Transport and Storage options for different CO2 qualities from the EII. Regulation regarding the cross-border transportation of CO2 in Europe is in place.
	Alternative fuels developments	H2 is not at a commercial level yet. Energy prices are still a burden for CCUS. The current high prices of energy make that additional costs of production are passed on to consumers.
Environmental	Adverse effects of Climate Change.	Climate Change has impacted society-wide as expected under a scenario of global warming below 1.5C.
Social	Social acceptance (NIMBY), NGOs against storage, elections, etc.	It implied that NGOs and society at wide accept that every solution to mitigate the adverse effects of climate change counts (No perfect solution). Supporting local economies (European EII is used as an ideology to create intersubjective meaning between the different sectors of society).

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More Economic Incentives and More Competitiveness Protection (+/+)

Table 54: List of impacts of Scenario 2.

Category	Trends	Potential impacts of trends
Economical	Financing (durability of SDE++ extended beyond 15 years).	It impacted by filling the uncertain and dynamic gap between abatement costs and the (certain) CO2 price within the EU ETS. Extending the durability and budget of the SDE++ policy instrument in case necessary.
	CBAM is in place	Criticisms of Green Protectionism
	Regulations did create a market for CO2-derived products	A minimum quota on low-carbon or CO2-derived commodities is in place. It further implies that the CBAM enters into force. Implies to regulate and incentivize the circular economy approaches, beyond the EII.
Political	Carbon Taxes and price of allowances increase	This is reflected in an increase in production and consumer costs. Avoid competition loss, implies having the effects of the Social Climate Fund received. In this sense passing on additional production costs to consumers is compensated. Avoiding carbon leakage implies having the CBAM in place to protect the increasing production costs from the European EII as compared to non-European EII.
	Future prices of CO2 do become certain	This implies having a Carbon Tax in Europe, the 4th Phase of EU ETS as planned, either a Carbon Price Floor or a reformed Market Stability Reserve, and the entering of CBAM into force.
	Liability is not shared in a Public-Private arrangement	It implies having a clear allocation of risks between each process of capture, transport, and storage.
Technological	Transitional tech (15y with 6y time to put projects to run).	In the case that CCUS is a transitional technology with a timeframe of 15 years, this would require additional investments to adopt the next decarbonization technology. The EII sees this trend as a risk that might lead to carbon leakage. To avoid this perception, the SDE++ should anticipate this possibility by giving certainty of future access to the same policy instrument to other related technologies that we as a

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		society might transition towards or to related technologies that the EII might need (e.g. H2).
	Transport and Storage Capacity is enough, 'quasi' affordable, and seamless.	Transport and Storage of CO2 became mainstream. There is a market for transport and storage. There are Transport and Storage options for different CO2 qualities from the EII. Regulation regarding the cross-border transportation of CO2 in Europe is in place.
Environmental	Adverse effects of Climate Change.	Climate Change has impacted society-wide as expected under a scenario of global warming below 1.5C.
Social	Social acceptance (NIMBY), NGOs against storage, elections, etc.	It implied that NGOs and society at wide accept that every solution to mitigate the adverse effects of climate change counts (No perfect solution).

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Less Economic Incentives and Less Competitiveness Protection (-/-)

Table 65: List of impacts of Scenario 3.

Category	Trends	Potential impacts of trends
Economical	Financing (durability of SDE++ remains 15 years).	Decarbonization costs are partially covered by the SDE++ scheme and additional costs are passed to consumers. It is impacted by not filling the uncertain and dynamic gap between abatement costs and the (certain) CO2 price within the EU ETS. Decarbonization costs are partially covered by the SDE++ scheme and additional costs are passed to consumers. Not extending the durability and budget of the SDE++ policy instrument in case necessary.
	CBAM is not in place	This is reflected in an increase in production and consumer costs. Competition loss. Carbon leakage.
	Regulations did not create a market for CO2-derived products	No minimum quota on low-carbon nor CO2-derived commodities is in place. It lowers the incentives to invest in low-carbon nor CO2-derived commodities. The circular economy is affected.
Political	Carbon Taxes and price of allowances increase	This is reflected in an increase in production and consumer costs. Competition loss. Carbon leakage.
	Future prices of CO2 do not become certain	This implies that either a Carbon Tax in Europe, the 4th Phase of EU ETS as planned, or the entering of CBAM into force failed to unfold its objective. Increasing uncertainty on decarbonization investments and costs.
	Liability is not shared in a Public-Private arrangement	There is a clear allocation of risks between each process of capture, transport, and storage. Industrial firms would experience higher risks for investments. However, there is additional funding covering such costs and leading to the adoption of CCUS.

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Technological	Transitional tech (15y with 6y time to put projects to run).	In the case that CCUS is a transitional technology with a timeframe of 15 years, this would require additional investments to adopt the next decarbonization technology. The EII sees this trend as a risk that might lead to carbon leakage. If the SDE++ does not anticipate this possibility by giving certainty of future access to the same policy instrument to other related technologies that we as a society might transition towards, another policy instrument should fill this gap (e.g. other subsidies to finance H2 projects).
	Transport and Storage Capacity is enough, 'quasi' affordable, and seamless.	Transport and Storage of CO2 became mainstream. There is a market for transport and storage. There are Transport and Storage options for different CO2 qualities from the EII. Regulation regarding the cross-border transportation of CO2 in Europe is not in place.
	Alternative fuels developments	H2 is not at a commercial level yet. Energy prices are still a burden for CCUS. The current high prices of energy make that additional costs of production are passed on to consumers.
Environmental	Adverse effects of Climate Change.	Climate Change has impacted society-wide as expected under a scenario of global warming below 1.5C.
Social	Social acceptance (NIMBY), NGOs against storage, elections, etc.	It implied that NGOs and society at wide accept that every solution to mitigate the adverse effects of climate change counts (No perfect solution). Supporting local economies (European EII is used as an ideology to create intersubjective meaning between the different sectors of society).

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More Economic Incentives and Less Competitiveness Protection (+/-)

Table 76: List of impacts of Scenario 4.

Category	Trends	Potential impacts of trends
Economical	Financing (durability of SDE++ extended beyond 15 years).	It impacted by filling the uncertain and dynamic gap between abatement costs and the (certain) CO2 price within the EU ETS. Extending the durability and budget of the SDE++ policy instrument in case necessary.
	CBAM is not in place	This is reflected in an increase in production and consumer costs. Competition loss. Carbon leakage.
	Regulations did not create a market for CO2-derived products	No minimum quota on low-carbon nor CO2-derived commodities is in place. It lowers the incentives to invest in low-carbon nor CO2-derived commodities. The circular economy is affected. Implies to regulate and incentivize the circular economy approaches, beyond the EII.
Political	Carbon Taxes and price of allowances increase	This is reflected in an increase in production and consumer costs. Competition loss. Carbon leakage.
	Future prices of CO2 do not become certain	This implies that either a Carbon Tax in Europe, the 4th Phase of EU ETS as planned, or the entering of CBAM into force failed to unfold its objective. Increasing uncertainty on decarbonization investments and costs.
	Liability is not shared in a Public-Private arrangement	There is a clear allocation of risks between each process of capture, transport, and storage. Industrial firms would experience higher risks for investments. However, there is additional funding covering such costs and leading to the adoption of CCUS.
Technological	Transitional tech (15y with 6y time to put projects to run).	In the case that CCUS is a transitional technology with a timeframe of 15 years, this would require additional investments to adopt the next decarbonization technology. The EII sees this trend as a risk that might lead to carbon leakage. To avoid this perception, the SDE++ should anticipate this possibility by giving certainty of future access to the same policy

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		instrument to other related technologies that we as a society might transition towards or to related technologies that the EII might need (e.g. H2). Regulation regarding the cross-border transportation of CO2 in Europe is not in place.
	Transport and Storage Capacity is enough, 'quasi' affordable, and seamless.	Transport and Storage of CO2 became mainstream. There is a market for transport and storage. There are Transport and Storage options for different CO2 qualities from the EII.
Environmental	Adverse effects of Climate Change.	Climate Change has impacted society-wide as expected under a scenario of global warming below 1.5C.
Social	Social acceptance (NIMBY), NGOs against storage, elections, etc.	It implied that NGOs and society at wide accept that every solution to mitigate the adverse effects of climate change counts (No perfect solution).

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Phase 3. Visions of the desired future (Where do we want to go?)

Vision: A Low-Carbon & Energy Industry (L-CEI).

The heavy industry is no longer referred to as the EII. It has been renamed as the L-CEI.

In 2032, the EII in The Netherlands and Belgium adopted CCUS by solving five major challenges: a) social acceptance of offshore CCUS projects, b) technological limitations to the commercial readiness of CCUS and H2 technologies, c) political and policy agenda to decarbonize the EII (observing 2030 and 2050 climate-related compromises while ensuring local industry competitiveness), d) economic (a lack of revenue schemes/flows in BM aiming at supporting the adoption of CCUS), and e) environmental (society at wide contributed to keeping global warming below 1.5C towards 2050). More in-depth, in 2032, we live in a context in which environmental compromises to keep global warming below 1.5C are supported by available technologies at a commercial level (TRL9 or higher) which have proved the potential to address the magnitude of such environmental compromises. Moreover, CCUS has a well-developed carbon market (mainly for permanent sequestration of CO2) that provides a revenue model to existing business models. Other promising technologies such as Green Hydrogen gained a TRL9-10. The EU's reached its ambitious target of having 20 million mt/year of available green hydrogen from 2030. Green H2 applications power heavy industry. Public and private efforts took enormous steps to develop hydrogen-based direct reduced iron [DRI] and hydrogen blending in DRI or blast furnaces.

Carbon Taxes and the post-Phase 4 of the EU ETS helped cut emissions from the EII, and other economic sectors. Production costs for low-carbon commodities related to the EII reached an equilibrium. The economic competitiveness of local industries plays a level field with non-European ones. EU policies and standards for low-carbon production have reached out to foreign legislation establishing a benchmark for less developed economies. Low-carbon commodities production costs within the EU are competitive and comparable to non-European ones. These developments are also visible in the way different legislations around the world internalized environmental costs. Internalization of environmental costs has diminished the risk of carbon leakage to jurisdictions with less stringent climate targets. Up to 2032, there Is no evidence proving carbon leakage or competition loss.

The CBMA has shown to be an effective policy instrument to protect the competitiveness of the local industry and to incentivize other countries to decarbonize their EIIs. On a similar note, the end of 4th phase of the EU ETS In 2032 set the ground for a competitive low-carbon Industry by achieving to reduce emissions by 61% (compared to 2005). The 5th Phase of the EU ETS looks forward to reaching climate neutrality by 2050. The overall energy mix is slightly beyond 40% compound of renewable energy (Union-wide). From a broader perspective, the Fit for 55

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Package has effectively demonstrated that a fair and socially just transition toward Industrial decarbonization Is possible while observing a competitive and Innovative EU Industry.

The SDE++, Carbon Taxes, the CBAM, and the EU ETS policy instruments have been shown to deliver environmental and economic effectiveness by achieving mitigation objectives minimizing costs, and maximizing benefits. Moreover, these instruments have safeguarded the distributional effects dimension by protecting the most vulnerable sectors during decarbonization transitions (e.g. vulnerable consumers). The Netherlands, Belgium, and the EU have placed *Institutional* measures to implement and monitor initiatives, emissions, and enforcement of compliance.

To arrive at an L-CEI, innovation, demonstration, and implementation of low-carbon technologies received public funds to help bridge the gap of lacking revenue streams In the last decade. In doing so a carbon market and a low-carbon commodities market were supported by regulation and public funding. In 2032, carbon pricing is certain and stable. The SDE++ is a mature instrument that delivers certainty to the industry and anticipates to further decarbonization ambitions and related technological innovation to be supported (toward 2050).

To mention one example of the scene of CCUS In 2032, the *Porthos* project in the Rotterdam port area Is Europe's largest carbon capture and storage facility. It has been reducing the country's CO2 emissions by 2% per year. As a hub, It distributes captured CO2 to different storage sites by pipes and ships. A European network of CO2 transport allows Industries and transport providers to operate without borders. This is well supported by cross-border policy instruments. At the European level, a central bureau coordinates transactions related to CO2 transport and storage within EU members. For example, Dutch and Belgian Industrial firms contract the services of the Porthos project for CO2 transport, and the former transfer CO2 for permanent storage at *Northern lights* In Norway.

Public acceptance has been and will remain dynamic. The last decade has experienced some public resistance to Inland CCUS projects and offshore projects to a lesser extent. As a dynamic force, public acceptance has moved Its attention to more recent technological advancements to further achieve climate neutrality by 2050. Nevertheless, the different societal sectors have witnessed the Impacts of climate change during the last decade. Although society *still* limits global warming to 1.5C, Its Impacts are evident and not contested. We have witnessed droughts, heat stress, species die-off, loss of entire ecosystems, famine, and loss of habitable land. As a result, society has come to the realization and awareness that we need to arrive at compromises and that perfect solutions do not exist. Similar to society's perception back in 2022 toward 2030, attention is now placed on 2050 and the ambitious targets that we as a society still need to accomplish.

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Phase 4. Public Policies and Firm Strategies (How do we get there?)

In Phase 4, we confronted the visions (as developed in Phase 3) with the different future environments as described in the external scenarios. In doing so, a SWOT analysis guided what public policies and firm strategies might be needed to arrive at an envisioned scenario. Table 17 organizes the identified public policies and firm strategies and categorizes them accordingly to each element of the proposed BMI framework.

Table 87: Arriving at Public Policies and Firm Strategies.

BMI framework elements	Vision's considerations	Public Policies and Firm Strategies to be considered (from t_0 to t_x)
Customer Value Proposition	Industrial firms offer low-carbon products to customers.	Industrial firms benefit from a tax incentive for providing low-carbon commodities or captured CO2 for utilization (with an obligation, a stick policy effect'). Moreover, a demand-side management approach offers tax incentives to customers to purchase low-carbon commodities and captured CO2 for utilization (with an obligation, 'a stick policy effect').
Customer Segment	Focus on existing customers.	Regulation/standards for minimum use of low-carbon materials per specific Industry (different than the heavy industry).
	The willingness of customers to pay for a premium price.	Public procurement (e.g. new buildings or new fleets by public entities and firms, this helps creating new markets and premium prices). Industrial firms benefit from a tax incentive for providing low-carbon commodities or captured CO2 for utilization (with an obligation, 'a stick policy effect'). Tax incentives to customers to purchase low-carbon commodities and capturedCO2 for utilization (with an obligation, 'a stick policy effect').
Revenue Model	Additional sales of premium-price products.	After the premium revenue from low-carbon commodities or captured CO2 for utilization becomes marginal, industrial firms could be granted a tax benefit (VAT reduction or 0%).

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	There is a market for captured CO2 for utilization.	Tax benefit (VAT reduction or 0%).
	CCS projects have enhanced the viability of CCU projects.	CCS has been approached by public Incentives while CCU has been left to the market. CCU projects need a stimulus (an obligation quota for sourcing production inputs by other industries from CO2 utilization).
Cost structure	Green electricity projects are more certain and have become de-risked by CCU projects.	Utilization has opened a market for methanol and other fuels. Therefore, an obligation quota for sourcing production inputs by industries from CO2 utilization is in place.
	Industrial firms have reduced emissions and therefore avoided some costs of CO2 (based on ETS) through implementing CCS.	CCS is implemented as scheduled. Guarantees for the EII are in place. This might help having CO2 capture technologies deployed on time by the EII.
Resources	Internal financial resources	Sales of low-carbon commodities and sales of CO2 for utilization (VAT reduction or 0%, and an obligation quota for sourcing production inputs by other industries from CO2 utilization).
	External financial resources: innovation fund (EU) or State Aid.	To fund additional costs to CCUS, including related supporting technologies (e.g. Green H2). The Innovation Fund needs to become more accessible to the EII (facilitation). State Aid is likely to become an option to further support CCUS and H2.
	External financial resources: SDE++ for CCS OPEX (NL).	To fund additional costs to CCUS, including related supporting technologies (e.g. additional funding to CAPEX or Green H2). The SDE++ already supports Green H2. Cross-border policy instruments. For instance, the option to use the SDE++ for storage abroad (e.g. from Rotterdam to Northern lights in Norway).
	External financial resources: Liability guarantees	Each process provider Is liable for Its own process within the CCUS chain.
Ownership	Industrial firms own capturing plants.	Available (on time and specific qualities) and affordable technology for industrial firms is necessary.
	External parties such as Transport and Storage firms own transport and storage facilities for CCS.	This premise needs to become clear in the Joint Venture/Transport contract which states obligations, rights, and liability of each specific party involved in the chain of CCUS.

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6. Conclusions

This report describes the design and validation of a 1) business model innovation framework and 2) describes the scenario analysis results using input from stakeholders. For the BMI framework, the process of business model development and the configuration of elements is conceptualized. Input from stakeholders was also used to forecast economic, technological, and socio-political developments influencing the Business Model options that enable adopting CCUS. In doing so, four external scenarios were developed. These scenarios shed light on potential opportunities and threats to anticipate. A vision scenario is provided which led to the arrival of Public Policies and Firm Strategies to support the adoption of CCUS in the next decade.

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Annex 1. Interview Guidelines.

Introduction:
- Name, affiliation and position in the organisation

Open questions:
- How is CC/U/S part of the GHG emission reduction plan of your company?
- Which part of the chain of CC/U/S is relevant to your company?
- At which stage of adoption (Initiation, Decision, Implementation) of CC/U/S is your company?
- What are the three main barriers to the adoption of CC/U/S in your company?
- What are the three main enablers for the adoption of CC/U/S at your company?
- What kind of uncertainties does your company relate to the adoption of CC/U/S?

Business model elements:
- Has your company already had a customer value proposition for products and services after CC/U/S is adopted? could you share it with us?
- Does your company expect that a low carbon/sustainable product (e.g. steel, chemicals) could be sold at a price premium? What is the view of your company?
- Whom has your company identified as target customers for its low-carbon product? Who is the main customer? (current customers or mostly new ones?)
- Does your company have estimates on the percentage of the extra price that your customers would be willing to pay for your low-carbon products/services? If so, what is that?
- How does your company generate revenues of CC/T&S? (e.g. direct subsidy from the government for storing CO2, revenue from selling carbon credits and CO2, others)
- What is the most economically feasible technology for large-scale CO2 utilization in the near future for your company/your potential customers? (Enhanced Oil Recovery (CO2-EOR), food-grade CO2 sales, organic transformation, microbiological culture, other)
- How does your company generate revenues from CO2 utilization? (e.g. storage subsidy, discounted price on the purchased CO2, others) What is the cost per tonne of CO2 utilized? What is the revenue per tonne of CO2 utilized?
- Are there other financial costs beyond costs of equipment, operation, and maintenance of capture, transport, utilization, and storage of CO2 for your company?
- Does your company expect that CC/U/S project should be financed as a whole full-chain CC/U/S project or as part-chain models? why?

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- Who does your company expect to bear the responsibility of financing different parts of CC/U/T&S applications?
- What type of ownership (owning shares/stakes/assets) for capturing plant/T&S infrastructure does your company prefer? Why?
- How does the adoption of CC/U/S by other interrelated organizations (including your collaborating partners and competitors) could influence the adoption of CC/U/S in your company?
- How does the adoption of CC/U/S affect the competitive advantage of your company in the market?
- Is your company/organization subject to losing competitive advantage because CC/U/S costs cannot be passed on to consumers in globally-traded commodities?
- What is the preferred type of business model from your company's point of view? (e.g. Vertical integration, operator, transporter, joint venture, or combinations/extensions of them) Could you describe the elements of the preferred BM? Why does your company prefer this BM?
- What are your key criteria for developing a business case around CC/U/S (e.g. revenue certainty, mitigating cross-chain risk, simple/transparent policy support, clarity on project ownership, Availability of funding sources for project development, etc.)?
- Which support mechanisms does your company prefer as most likely to support a revenue stream for the CC/U/S? (Contract for difference on CO2 price, cost plus open book, regulated asset base, tradeable tax credits, product CO2 taxes (redistributed), tradeable CCS certificates, EPS + tradeable CO2 credits, Low carbon market creation through regulation)
- What changes does your company envision to occur in the elements of your preferred CC/U/S business model (e.g. financing or funding) in the future (say after 2030)?
- What does your company expect of the implications of those changes?

Policy:
- What public policy instruments are desirable for your organization that could support your business case for CC/U/S adoption?
- What existing public policies and regulations does your organization find supporting/hindering the adoption of CC/U/S in your company?
- What public policies or regulations has your organization proposed or lobbied for that could support CC/U/S adoption in your company?

General question:
- Could you give a quantitative estimate of the costs of CC/U/S implementation for your company and if so would you be able to share them (or data on emissions scale and purity)?

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Other adoption elements:

For your company, what are the relative advantages of adopting CC/U/S compared to other (GHG emission reduction) technologies or options that are available? How did it play a role in the consideration to adopt CC/U/S?

- How does CC/U technically integrate with your current operations? Does it require changes in the flow or structure of the operations and their outcomes? How did it play a role in the consideration to adopt CC/U/S?
- What is the perception of your company on the difficulty to understand CC/U/S technologies? (complex or simple technologies) How did it play a role in the consideration to adopt CC/U/S?
- What is the perception of your company on the difficulty to use CC/U technologies? (complicated to use, the application requires skills beyond what is currently available at the company) How did it play a role in the consideration to adopt CC/U/S?
- Has your company had access to the results of the ongoing CC/U/S project? How did it play a role in the consideration to adopt CC/U/S?
- How does the availability of different resources such as capital invested in the business, R&D investment level, skilled workforce, volume, and value of inputs and outputs in your company influence the adoption of CC/U/S? How did they play a role in the consideration to adopt CC/U/S?
- At which level of your organizational hierarchy are decisions related to the adoption of CC/U/S made? How does the distribution of decision-making power in your organizational hierarchy influence the adoption of CC/U/S for your company?
- Has your company ever engaged in (informal) networks with other potential adopters of CC/U/S to share information? If so, what type of information has been shared in the networks?
- If the answer to the above Q is yes, has the information influenced the decision of your company to adopt CC/U/S?

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