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Abstract

This interim report presents the second phase status of the Business Case Development work under the ELEGANCY project. It further develops the details within the overall methodology that is characterized by a number of steps to i) define the scope of the H_2-CCS chain subject to a particular ELEGANCY case study, ii) perform a focussed market background review and gap analysis, iii) identify business and investment risk and corresponding risk mitigation strategies, and iv) develop business models. Step ii) is completed and Step iii) is covered in this interim report, which comprises policy requirements, their impact on business investment and operations, risk assessment, and the types of risk mitigation measures available to both public and private sectors.

A recap is provided of the methodological approach introduced in report D3.2.1 for the characterization of the business context of a case study and completes the suite of assessment tools to include policy gap and risk analyses. This is followed by a detailed summary of government policy requirements to facilitate the technology innovation, market creation and infrastructure investability for the delivery of large scale H_2-CCS chains. The concepts of investment and business risk, investment barriers and principles of risk allocation are described, and followed by the presentation of a portfolio of options to address investment barriers in the five case study countries. The issues and needs facing the different types of major stakeholders in H_2-CCS chains when considering business risks are discussed, and the mechanisms for sharing and allocating those risks explored. A portfolio of standard options to address business risks in commercial and finance contracts is presented. The report is completed with an example summary outcome of a policy and risk assessment following the WP3 methodology.

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ABBREVIATIONS

ACQ	Annual Contract Quantity
ADB	Asian Development Bank
AFC	Alkaline Fuel Cell
BEV	Battery Electric Vehicle
C&I	Commercial and Industrial
CCS	Carbon Capture and Storage
CCSA	Carbon Capture and Storage Association
CCUS	Carbon Capture, Utilisation and Storage
CER	Certified Emissions Reduction
CDM	Clean Development Mechanism
CH_4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
DCQ	Daily Contract Quantity
CPG	CO_2 Plume Geothermal
DME	Dimethyl Ether
DMFC	Direct Methanol Fuel Cell
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EIB	European Investment Bank
EGR	Enhanced Gas Recovery
EPC	Engineering, Procurement and Construction
EOR	Enhanced Oil Recovery
ETS	Emission Trading Scheme
EV	Electric Vehicle
FC	Fuel Cell
FCEB	Fuel Cell Electric Bus
FCEV	Fuel Cell Electric Vehicle
FID	Final Investment Decision
GoO	Guarantees of Origin
gridE	Grid Electricity

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GT	Gas Turbine
GTR	Global Technical Regulation
H_2	Hydrogen
HFC	Hydrogen Fuel Cell
HFC(E)V	Hydrogen Fuel Cell (Electric) Vehicle
HRS	Hydrogen Refuelling Station
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle power plant
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
JRC	Joint Research Centre (EC)
LCA	Life Cycle Analysis
MDQ	Maximum Daily Quantity
MCFC	Molten Carbonate Fuel Cell
NDC	Nationally Determined Contribution
NDQ	Nominated Daily Quantity
NG	Natural Gas
O&M	Operation and Maintenance
P2G	Power to Gas
P2L	Power to Liquids
P2X	Power to X (X = gaseous or liquid energy carrier)
PCI	Project of Common Interest (EU)
PoR	Port of Rotterdam
RE	Renewable Energy/Electricity
SMR	Steam Methane Reforming
SPV	Special Purpose Vehicle (Company)
TFEU	Treaty on the Functioning of the European Union
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Framework Convention on Climate Change
WP	Work Package
WTO	World Trade Organisation
ZEP	Zero Emissions Platform

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1 INTRODUCTION

The world faces an unprecedented challenge in reducing CO_2 emissions and achieving climate objectives in a competitive and global economic context. There is a growing consensus that CCS is critical to the low carbon energy transition and to achieving deep reductions across many sectors[1].

The major barrier to deployment of CCS is no longer technological, but political and commercial. According to the IEA[2], "there are 21 large-scale, integrated projects operating or under construction throughout the world and across various applications, including coal-fired power generation, natural gas processing, steel manufacture and oil sands upgrading. These projects are in addition to around 100 pilot plants and an extensive global research and development (R&D) push". There remain many technical challenges associated with the successful development and operation of CCS systems, but the general agreement is CCS at industrial scale is technically feasible.

However, the successful realisation of such large-scale low carbon infrastructure investment requires the mobilisation of vast amounts of domestic and international private capital (equity and debt) to supplement limited government resources and facilitate a more efficient use of those resources by sharing the risks with private sector. Large scale infrastructure investment due to its nature requires government involvement – direct or indirect to address fundamental investment barriers. Policies are critical in determining the attractiveness of investment opportunities and their risk profile. In addition, these opportunities face traditionally many other challenges such as cost overruns, delays, availability of private finance, demand/volume uncertainty and therefore risk of oversizing, counterparty credit risk, etc.

Risks - whether perceived or real - determine the attractiveness of the investment opportunities and the level of return investors expect, and it is therefore critical to understand, mitigate and allocate risks which private sector lenders and investors perceive as excessive or beyond their control and are not willing to accept. Good management of risks also determines the overall value realised by the execution of the project. In a review of infrastructure projects, McKinsey[3] concluded that "large infrastructure projects suffer from significant undermanagement of risk in practically all stages of the value chain" and highlighted the need for good risk-informed project management made up of a risk management framework which identifies the most critical issues and choices to be made, a set of practical tools to help public and private investors make those choices, and an implementation framework to ensure disciplined execution throughout the life cycle of the project.

[1] Zero Emissions Platform, (2018), *Role of CCUS in a below 2 degrees scenario*, http://www.zeroemissionsplatform.eu/library/publication/282-ccusbelow2degrees.html, (accessed 30.7.2018)
[2] IEA, (2017), *Five keys to unlock CCS investment*, https://www.iea.org/media/topics/ccs/5KeysUnlockCCS.PDF, (accessed 30.7.2018)
[3] Beckers, F. and Stegemann, U., (2013), *A risk-management approach to a successful infrastructure project*, McKinsey, https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/a-risk-management-approach-to-a-successful-infrastructure-project, (accessed 30.7.2018)

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With regard to H_2-CCS infrastructure investment, ClimateWise[4], a global insurance industry leadership group highlighted in 2012 that "the absence of viable risk management solutions presents a material barrier to the development of Carbon Capture and Storage (CCS) at scale in Europe". In Europe, the combination of high capital costs, low and unpredictable carbon prices, dependency on public policy and financial support at time of tight national budgets, immature regulatory framework, credit risk across the infrastructure chain represents a major investment challenge which, without a clear risk management and allocation model, increases the risk perceptions and profiles significantly for the potential investors especially in a global financial market competing with more mature infrastructure investment opportunities.

The successful realisation of large H_2-CCS network investment will need good decision making and risk management framework to identify and track critical investment barriers and major business risks and find risk management solutions applicable to the relevant H_2-CCS chain throughout the life cycle of the project.

Work Package 3 (WP3) is about developing a risk-centred framework applicable to any case studies to facilitate the development of suitable business models, i.e. those which allow a suitable risk allocation and delivery of profitability and value in order to facilitate the necessary private and public investment in an effective manner. WP3 focuses on providing the methodology, tools and guidance necessary to allow private and public entities to discuss and determine the appropriate business model which works in the specific context of the country and case study, rather than providing a recommendation on the ideal business model. The main objectives of WP3 are to develop a business case framework comprising:

- a number of guided assessment tools for the legal, market, macro-economic, fiscal and policy background relevant to integrated H_2-CCS chains; and
- a suite of optional elements for constructing business models, which can be applied:
  within ELEGANCY in the WP5 case studies; and
  beyond ELEGANCY in any other European country wishing to explore opportunities for H_2-CCS chains.

This report is structured as follows.

Chapter 2 recaps the methodological approach introduced in report D3.2.1 for the characterization of the business context of a case study and completes the suite of assessment tools to include policy gap and risk analyses.

Chapter 3 provides a detailed summary of government policy requirements to facilitate the technology innovation, market creation and infrastructure investability for the delivery of large scale H_2-CCS chains. It is complemented in Appendices B-G with a review of current European and ELEGANCY Case Study country policies that are relevant to the development, deployment and operation of H_2-CCS chains.

Chapter 4 presents the concepts of investment and business risk, investment barriers and principles of risk allocation.

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[4] ClimateWise, (2012), *Managing Liabilities of European Carbon Capture and Storage*, https://www.cisl.cam.ac.uk/publications/sustainable-finance-publications/remove-obstacle-carbon-capture-and-storage, (accessed 30.7.2018)

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Chapter 5 presents a portfolio of options to address investment barriers present in the five case study countries.

Chapter 6 discusses the issues and needs facing the different types of major stakeholders in H_2-CCS chains when considering business risks, and the mechanisms for sharing and allocating those risks. The chapter also presents a portfolio of standard options to address business risks in commercial and finance contracts.

Chapter 7 presents an example summary outcome of a policy and risk assessment following the WP3 methodology.

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2 METHODOLOGY

2.1 Summary

The ELEGANCY WP3 business model development methodology was described in report D3.2.1 and is re-presented in Section 2.2 below for convenience. WP3 follows a structured and methodological approach. The earlier deliverable D3.2.1 provided the relevant methodology (along with guidance and tools) to define and frame the scope of the case study and facilitate the assessment of their regulatory, fiscal, macro-economic and market background to allow the case study team to gain an early understanding of the main elements of business context which impact investment and commercial decision-making. This chapter extends the background characterisation to policy assessment and moves to the next stage of identification of business risks and investment barriers (i.e. key factors that make business risks excessive for private investors to bear) for each business sector of the H_2-CCS chain and the review of de-risking instruments including the role of government, and other commercial and financial mechanisms. Additional assessment spreadsheet tools have been created for analysis of policy gaps, investment barriers, business risks and mitigations options. These have flexible application for use with all the business segments of the H_2-CCS chain and are provided as additional separate files to this report.

The full suite of methods and tools comprising the methodology allows for a complete assessment of the main elements of the business context and risks for any case study. They are designed for a multi-disciplined collaborative approach to selecting business model preferences that includes legal and policy experts as well as technical, commercial, financial and social experts; such expertise may be sourced internally or externally, i.e, by contracting reputable external parties or through the voluntary participation of industry and trade associations depending on the case study development stage and resources available. This business model selection process will be described in the subsequent report D3.3.3.

This overall process and methodology is planned to be iterative and part of a risk management framework repeated at various stages of the case study development with increasing levels of detail – similar to the stage gate process used for investment decision making in private companies. Early case study background assessment and identification of major business risks and investment barriers allows the case study to prioritise issues to be addressed and provides the focus for an early engagement between public and private entities to discuss private/public risk allocation and the nature of government intervention.

The Zero Emissions Platform has established a temporary working group "Collaboration across the CCS chain" to assist WP3 with the identification and mitigation of investment barriers and business risks. Recommendations arising from the ZEP working group will be used to test and improve the methodology, and to provide the foundation for the final step of selecting business models.

2.2 Business Model Development Methodology

The flowchart in Figure 2-1 presents the overall methodology developed and applied by WP3 to select business models and assess potential business cases for H_2-CCS opportunities (see ELEGANCY report D3.2.1).

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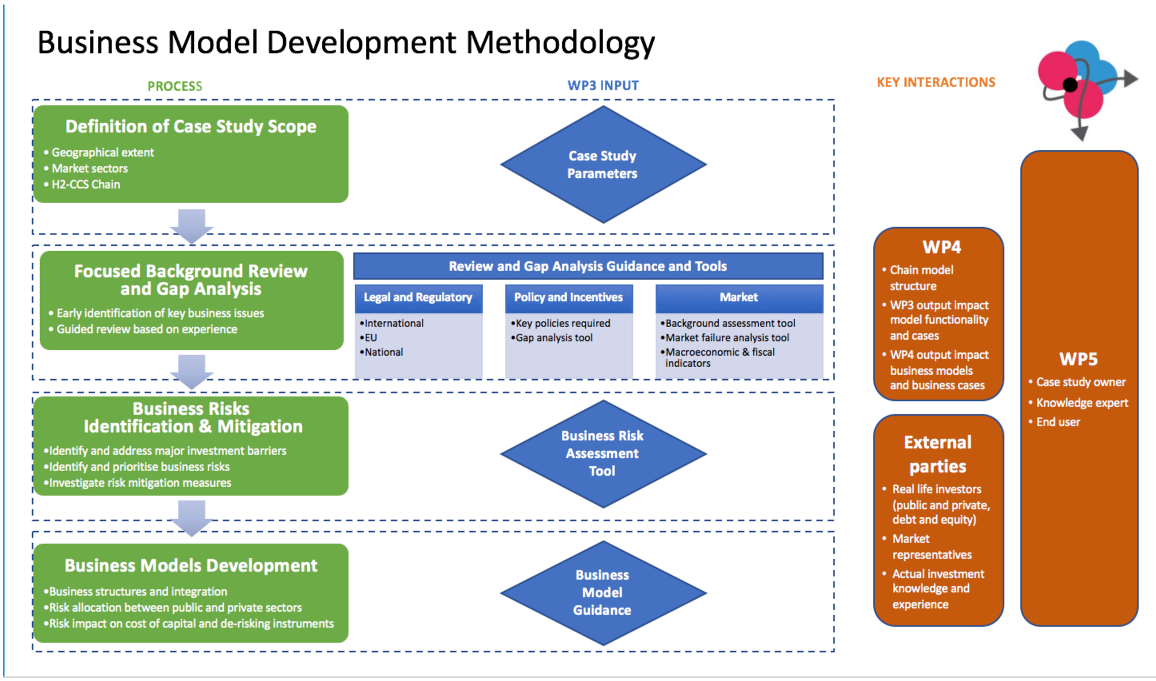

Figure 2-1 Business Model Development Methodology

The process is divided into a number of distinct steps:

Step 1: *Definition of the scope of the particular H_2-CCS chain for the relevant case study*

The process commences with an initial focus on the specific H_2-CCS chain technical sub-components, business segments, and associated market sectors of main interest, the geographical extent (including industrial hubs, production facilities, storage areas, end-users, cross-border interactions, etc.), and market potential.

First Climate and Sustainable Decisions have created a standardised framework for any case study lead organisation to use in this first step that matches the needs of the scope definition exercise described above. This framework comprises the technology elements and market sectors, a H_2-CCS chain business tree, and an extensive set of potentially relevant case study parameters (described in report D3.2.1). This framework and analysis are to be used side-by-side with the scenarios and quantitative estimates of market potentials undertaken in Work Package 5 *Task 5.1 Interfaces* and reported in D5.1.1.

Step 2: *Focussed market background review and gap analysis*

The purpose of this second step is to guide an overall assessment of the market background for any case study in preparation for the third step of understanding the investability and handling of major business risks. The major barriers and business risks that are faced by potential developers and financiers in the H_2-CCS business chain have been identified by stakeholders to be non-technical, and robust economic scrutiny is essential for any large-scale infrastructure investment. Technology components within the H_2-CCS infrastructure chain and end markets exist and have proven functionality. Hence, investing in, and delivering, low-carbon hydrogen using CCS at scale requires an understanding of the risks

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associated with government policy, market development, and regulatory frameworks. Full chain operability issues are another area of risk that is dealt with in Step 3 below.

A set of Excel spreadsheet tools (Report D3.2.1 and Appendix A.1) has been designed and produced, based on the project development experience gained over a number of years in countries such as Netherlands, Norway and UK, to facilitate a simple high-level analysis of the major drivers for each of the H_2-CCS chain market sectors and business segments. The market background includes the legal and regulatory environment, the market fundamentals and applicable market failures, key macroeconomic drivers, the policy status and financial support mechanisms. An important aspect of this assessment method is the requirement to include thinking and review of the interactions between different market players reflected in the chain business segments.

Step 3: *Business and investment risk identification and mitigation*

Based on the information gathered during step 2, the third step is to identify and quantify the major business risks that impact the level of investment potential for each of the market sectors and business opportunities from both a public and a private sector perspective. A bespoke risk assessment spreadsheet tool has been designed (Appendix A.2) that can be applied to any individual or bundled business opportunities along the H_2-CCS chain selected from the standardised business tree.

Section 2.4 below describes the risk assessment methodology in more detail. In summary, assessable risks are divided into:

1. Investability Barriers: these are circumstances or facts that raise the risk of detrimental investment outcomes to an unacceptable level for any type of investor. Generally, these barriers will affect multiple segments along the chain, or the whole chain, and require a "system view" and multi-party (often in collaboration with government) approach to mitigation measures. These barriers need to be addressed in priority for any investment to be possible; and
2. Major Business Risks: these are risks that impact cost, revenue, liabilities, financing, schedule and therefore the risk/return equation for a final investment decision (FID). Individual businesses will generally be capable of mitigating these through familiar technical, commercial, insurance and other standard measures.

This step facilitates an early identification and prioritisation of risks to be addressed by a case study lead organisation and guide the subsequent communication and conversations with potential private investors and public/government organisations.

Step 4: *Business model development*

The fourth step in the method focuses on how to remove the investability barriers and mitigate business risks and to select appropriate business models for any given case study. Chapters 4 - 7 of this report deal with the principles and elements of the methodology which will be included in further tools for business model selection in the next WP3 deliverable, report D3.3.3. When applied to case studies, the outcome will be the development of a number of viable commercial structures and business models, investigating the potential investor mix and the allocation of risks between those investors

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for each of the market opportunities, the de-risking mechanisms required from the financial and carbon markets and from the EU and national governments.

2.3 Policy Gap Analysis

As we discussed previously, large scale infrastructure investment due to its nature requires government involvement – direct or indirect to address fundamental investment barriers and it is therefore essential to carry out a qualitative and quantitative assessment of existing regulatory, market-making, innovation and technology delivery policies and financial support mechanisms against expected requirements to identify existing gaps and guide conversations with the relevant government bodies.

The business context focussed background review and gap analysis of Step 2 described above is completed with the development and use of the "Policy Gap Analysis Tool" presented in Appendix A.1. The spreadsheet allows for a high-level policy and funding review by a policy expert with a focus on determining the main current policy status and trends. In keeping with previous tools described in D3.2.1, the tool is designed to produce a "heat map" allowing consolidation of policy information to identify major gaps, host government credibility vis-à-vis aspirational outcomes, and consistency with stakeholder/sector funding needs.

The tool is structured as follows. Firstly, the market sectors of relevance for the H_2-CCS integrated chain of the case study are selected. The market sectors are made up of a number of business segments that provide products or services, which are again taken from the business tree described in deliverable D3.2.1. These can be considered in greater detail during the course of the policy assessment and additional policy needs added to the spreadsheets as deemed appropriate.

For each of the relevant market sectors, the policies in place are reviewed against the identified "market needs". Three assessments are carried out.

1. First the importance of the policy need is rated using a simple scale of low/medium/high.
2. The second rating is an estimated time period over which the policy needs to be developed and implemented for maximum benefit to the evolution of the market sector and its associated technologies.
3. The third assessment is aimed at determining the level of compliance of existing policies for the case study under review. The level of compliance is rated from 1 to 10 (1=Not compliant; 10=fully compliant) and the user is asked to provide evidence. Cells automatically change colour in relation to the rating.

The final aspect of this rating tool is a review of the level of financial support available for the implementation of the relevant policies and activities to determine whether this is currently sufficient. Multiple options are provided: very low and low (i.e. insufficient), sufficient, and high (which has a positive impact on the timeline for implementation). The user is again asked to provide evidence to allow for comparison with other case studies or market sectors and facilitate future revisions of the assessment.

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2.4 Risk Assessment

The risk assessment Step 3 in the methodology takes all of the background review and gap analysis of the business context and generates the risk matrix for a given case study. This step is undertaken using the "Risk Assessment Tool" presented in Appendix A.2.

This tool is designed to carry out a preliminary assessment of the investability barriers and major business risks in each of the market sectors/business opportunities of a specific case study in order to steer the development of the appropriate business model, and to define and prioritise the actions to be taken in order to mitigate and manage those risks. The risk assessment methodology is described in more detail below, and Figure 2-2 depicts the modified bow-tie assessment technique used as the basis for the methodology and matrix (Appendix A.2).

In addition to the master risk assessment tool, two exemplar assessments have been provided (Appendix A.2):

1. CO_2 transport and storage; and
2. Hydrogen production.

These exemplars provide some very detailed risk assessments for the selected business segments of an H_2-CCS chain in the UK. They are designed to provide guidance on how to interpret and use the various sections of the risk assessment tool and to encourage conversation and dialogue when using the master tool.

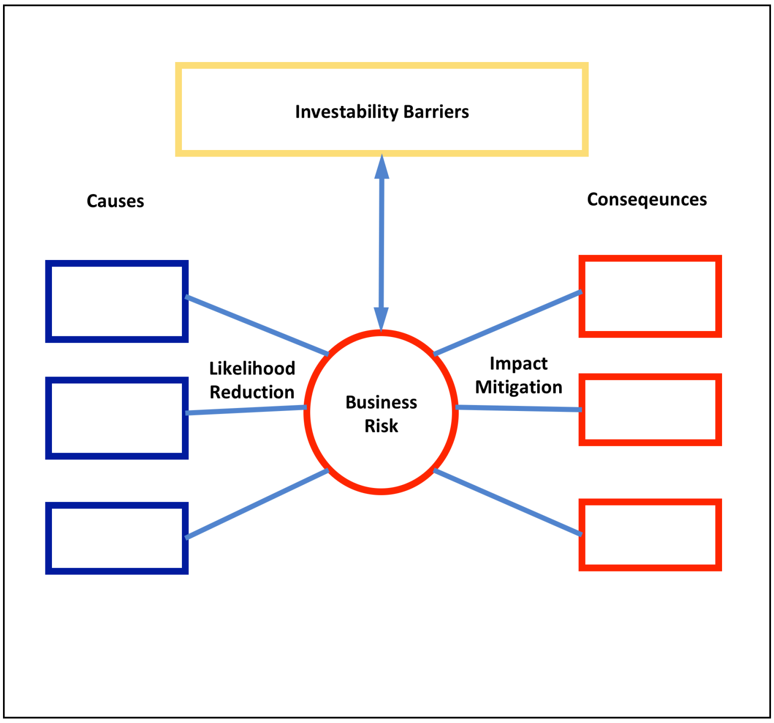

Figure 2-2 Modified Bow-Tie Risk Assessment

The risk assessment methodology is structured as follows.

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Step 1: *Identification of business opportunities*

The market sectors/business opportunities of relevance for the H_2-CCS integrated chain of the case study are selected to understand how many risk assessments need to be completed and to frame the analysis of each one depending on its level of integration. Business opportunities may be grouped together to represent vertical integration of the value chain components in one entity, those which are/will be managed by the same entity (public/private) or where the investment risks are fully integrated within the same entity. These business opportunities should be consistent with the H_2-CCS chain business segments of the business tree defined in deliverable D3.2.1).

Step 2: *Detailed risk assessment*

The risk assessment for the H_2-CCS chain is undertaken at two levels followed by a consistency check between the two:

1. At the first level, major investability barriers are identified. These barriers are "fact" or in risk parlance have 100% likelihood. These barriers affect investment in substantial parts or all of the H_2-CCS chain. A number of these barriers have been experienced by CCS projects and commercialisation programmes, and many have been well documented. Mitigation measures need to be identified to enable public and/or private sector entities to invest and operate. A market failure such as a missing market is an example of an investment barrier. A regulation or statute resulting in an uncapped liability for a business is another.

2. At the second level, specific business risks affecting each of the business opportunities are reviewed and their likelihood and impact on the feasibility or value of the business opportunity are assessed using a traditional risk matrix methodology. The consequences on investability are also rated using a scale from 1 to 5 where 1 is low risk and 5 is prohibitive risk. Guidance tables with qualitative description of the rating values for risk likelihood, risk impact and investability are provided in the instructions sheet to help the user. A degree of flexibility in interpretation is allowable for the severity of the impact depending on the nature of the proposed investment or operational entity. Mitigation measures for cause and consequence are then analysed using a bow tie approach, which addresses control and recovery actions for cause and consequence respectively. Those measures are categorised from a pre-defined list (contractual, legal, etc.) and assessed to understand their level of market development and whether government intervention is required.

Step 3: *Consistency check*

The impact of the business risks at the second level on investability in the business opportunity is also assessed from a chain perspective to determine if investability barriers and mitigations need to be reviewed and revised or the nature of the business entity needs to be modified. A consistency check between the investability barriers at level 1 and the business risks at level 2 is undertaken to ensure any level 2 risks that result in a chain investability impact of rating 5 are escalated to barriers and dealt with accordingly. Consistency between mitigation measures is also cross-checked.

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2.5 Risk Mitigation

Risk mitigation is an iterative process that parallels the typical project development stage gate process for decision making. The pre-defined list of risk mitigation measures categories included in the assessment tool described above has been designed to guide the user to also think about how the respective risk and measure may be shared. For example, a contractual means of mitigation will rely on two or more parties agreeing a commercial or legal allocation of the risk and its impact.

The WP3 business model development methodology allows for repeated use of the risk assessment tool at increasing levels of detail. Changing preferences in risk mitigation options as more insight is gained during case study analysis will lead to changing risk allocation between stakeholders and ultimately to alternative business models and commercial structures. This process will be further developed into new tools to support business model selection and will be reported in D3.3.3.

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3 HYDROGEN-CCS POLICIES

3.1 Summary and objective

The purpose of this chapter is to provide an overview of the innovation, market, and fiscal policies needed to overcome the inertia to technology innovation, market creation, and infrastructure investability for delivery of large-scale hydrogen networks and CCS chains.

The climate, economic and social contexts against which policies for H_2-CCS market and infrastructure development are presented first and are followed by a summary of the policy requirements for H_2 and CCS which have been distilled from recent expert reviews of the hydrogen and fuel cell (HFC) sector and its potential markets within a low carbon transition as well as reviews of the CCS sector comprising the current understanding of the delivery requirements for infrastructure, industrial emissions reduction and CO_2 utilisation. These reviews take account of the lessons learned over the last decade from European and national CCS demonstration programmes.

Appendices related to this chapter also provide a summary of current European and ELEGANCY Case Study country policies that are relevant to the development, deployment and operation of H_2-CCS chains. The policy environment in Brussels and nationally is very dynamic and this summary attempts to take account of the most recent policy announcements as of Summer 2018. While not exhaustive, it provides a useful snapshot of the contemporary thinking of governments in case study countries.

This chapter, and the complementary Chapter 3 *H_2-CCS Business Options* in Report D3.2.1[5], form the basis for assessing policy gaps, and market barriers and failures that work to discourage rather than facilitate investment in H_2 and CCS - both separately and in combination. These inputs are used in business risk assessment, risk allocation and sharing, and the development and selection of business for application in the case studies in Work Package 5.

3.2 Climate Context

Europe has recognised for some time the need for a major energy transition and the urgency to significantly reduce GHG emissions to address the climate challenge that humankind faces with its potential catastrophic consequences. The Paris Agreement[6] of the United Nations Framework Convention on Climate Change in 2015 was a landmark in its global efforts to limit the world's temperature to well below 2°C above pre-industrialised levels. However, as estimated by the IEAIEA/IRENA[7], achieving this objective requires double the current levels of investment in the energy sector, i.e. US$3.5 trillion globally on average each year until 2050. Multiple technology

[5] ELEGANCY D3.2.1, (2018), *Interim report detailing the regulatory, fiscal, and macro-economic background for each case study*,
[6] UNFCCC, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement, accessed 30.7.2018
[7] International Energy Agency and International Renewable Energy Agency, (2017), *Perspectives for the energy transition: investment needs for a low-carbon energy system*, http://www.irena.org/publications/2017/Mar/Perspectives-for-the-energy-transition-Investment-needs-for-a-low-carbon-energy-system, (accessed 30.7.2018)

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solutions will need to be deployed to solve this global problem as the scale of these reductions cannot be achieved by one technology alone.

There is a growing recognition[8] of the need to accelerate deployment of known technologies at the same time as continuing a major push for scalable new-generation breakthrough technologies born out of public and private global clean Research and Innovation (R&I). The most cost-effective way[9] of achieving a rapid energy transition is through coordinated efforts across the EU member states and internationally (c.f. Mission Innovation[10]) through a number of cooperative projects, information sharing and public-private partnerships.

The EU accepts[11] that it is not simply a question of backing individual technology options as each has its own challenges, and overall market deployment success is dependent on both economic attractiveness for private investment and financing, and on the consumer preferences which reflect national and regional contexts including existing infrastructure investments as energy systems become more decentralised and decarbonised. There are multiple energy pathways to facilitate such a transition and achieve the required reduction in GHG emissions, so it is critical to retain optionality and flexibility to integrate a broad range of technologies.

Clean Hydrogen and Carbon Capture Utilization and Storage are two technologies that can be integrated at scale in various energy systems across all the main CO_2 emitting sectors: industry, transport, heating, power generation[12]. In combination, they can form a highly cost-effective way of abating distributed emissions sources[13].

3.3 Economic and Social Context

The EU's Energy Policy has three main goals: security of energy supply, affordability (through minimising the cost to industry and consumers) and sustainability. Ultimately for climate mitigation strategies and policies to be effective there will need to be an evolution of new ways for economies to function: reducing demand on natural resources, placing appropriate value on natural capital, incorporating the cost of the current damaging CO_2 externality into the value of goods and services, creating new low carbon industries and services, and establishing a greater level of recycling and circularity[14].

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[8] See for example, UK Committee on Climate Change, (2018), *An independent assessment of the UK's Clean Growth Strategy*, https://www.theccc.org.uk/publication/independent-assessment-uks-clean-growth-strategy-ambition-action/, (accessed 30.7.2018)
[9] Pöyry, (2018) *Fully decarbonising Europe's energy system by 2050*, http://www.poyry.com/sites/default/files/media/related_material/poyrypointofview_fullydecarbonisingeuropesenergysystemby2050.pdf, (accessed 30.7.2018)
[10] Mission Innovation, http://mission-innovation.net
[11] European Commission, *SET-Plan*, https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan (accessed 30.7.2018)
[12] References IEA Hydrogen Implementing Agreement, (2017), *Global trends and outlook for hydrogen*, http://ieahydrogen.org/pdfs/Global-Outlook-and-Trends-for-Hydrogen_Dec2017_WEB.aspx, (accessed 30.7.2018)
[13] Pöyry, (2018), op. cit. Pöyry, (2018) *Fully decarbonising Europe's energy system by 2050*, http://www.poyry.com/sites/default/files/media/related_material/poyrypointofview_fullydecarbonisingeuropesenergysystemby2050.pdf. Pöyry, (2018), op. cit.
[14] United Nations, *Sustainable Development*, https://sustainabledevelopment.un.org/post2015/transformingourworld, (accessed 30.7.2018)

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Along with the restructuring of economies, there also need to be improved ways of evaluating the impact of low carbon infrastructure in order to differentiate between technologies, provide policy makers with better insights into the long term macro-economic and social benefits, and to facilitate decision making for both private sector investment and public sector financial support[15].

3.3.1 Sustainability and the Circular Economy

The twin objectives of sustainability and a circular economy are demanding challenges. Although the policy emphasis to develop, and lower the cost of, renewable power generation has been an essential aspect of climate mitigation efforts, the surge in renewable energy has, and is, creating new sustainability issues[16]:

1. It puts pressures on the supply of rare earth elements, and therefore causes new environmental impacts as well as new dependencies in the value chain that could result in possible future barriers to utilisation and growth.
2. The integration of increasing levels of variable electricity produced from renewables, such as wind and solar, in the electricity grids requires enhanced network management and energy storage for maintaining reliability of the overall system, and to balance supply and demand. Multiple forms of back up generation and energy storage suited to different geographies and applications are therefore needed to ensure reliability.
3. Highly electrified domestic heating and vehicle transportation sourced from renewable power would result in significantly increased levels of demand variability and interdependence. Very large amounts of installed generation capacity with associated high investment and operational costs, and low average inter-seasonal load factors would be required.
4. The environmental impact of some renewables, especially bioenergy, is controversial. Large land areas are required for forests and energy crops, which raises issues such as competition with food production and appropriate land use selection. Using biomass in power generation releases the CO_2 captured during the growth of the trees and crops when burnt, with a consequential need to capture those emissions. GHG emissions are still associated with growing and harvesting energy crops due to fertiliser production, modified soil absorption of CO_2, equipment use, and transportation.

The above highlight the increasing need to be able to design and manage life cycle emissions and reduce the embedded carbon in energy, products and services in developed and developing economies alike. A holistic or systemic approach to economic activity and growth, whether called a "circular economy" or simply "sustainability", is increasingly being recognised as a prerequisite to achieve climate targets and "clean" or low carbon growth.

[15] See for example, Turner, K., Alabi, O., Smith, M., Irvine, J., and Dodds, P. (2018). *Framing policy on low emissions vehicles in terms of economic gains: Might the most straightforward gain be delivered by supply chain activity to support refuelling??,?* Energy Policy, [online] 119, pp.528-534. Available at: https://www.sciencedirect.com/science/article/pii/S0301421518303033?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb, (accessed 30.7.2018)

[16] See for example: National Academy of Engineering and National Research Council, (2010), *The Power of Renewables: Opportunities and Challenges for China and the United States,* Washington, DC: The National Academies Press. https://doi.org/10.17226/12987

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Hydrogen could have a special role to play in the energy and economic transition to a sustainable circular economy. It can play a major role as a storage medium for electricity and therefore in the balancing of supply and demand. It is also a transportable fuel that can provide a large-scale alternative solution for the decarbonisation of distributed small emissions sources such as in domestic heating and vehicle transportation[17].

3.3.2 Low Carbon Industry and Growth

The implementation of national GHG reduction commitments and transformation of the world's energy systems can provide a stimulus for global technology cooperation and a major opportunity for European businesses, both established organisations and small innovative companies. The EU and individual member state governments have recognised the imperative to retain and increase the international competitiveness of existing energy intensive industries (such as cement, steel, petrochemical, refinery) and to use this opportunity to promote jobs and economic growth.

According to Eurostat[18],, employment in the environmental goods and services sector grew 13% in the five years from 2010, and included over 1.5 million people working on renewables and energy efficiency in Europe in 2015. EU companies have a leading global position in renewable technologies with a 40% share of all patents[19].

Existing manufacturers in multiple sub-sectors have the opportunity to modernise by embracing new technologies and exporting their products. Innovative companies can benefit from positive regulatory and financial environments to develop new products and services and grow rapidly.

During 2017 a number of EU countries announced similar "clean energy" strategies and budgets, which are focused on supporting and developing industries and clean economic growth. The choice is no longer between "green" and "growth" but has become "green and growth". These governments realise the potential to leverage the energy transition to strengthen their own energy sectors in order to create jobs, income and growth. These strategies and budgets generally provide strong financial support for innovation and SMEs in order to stimulate additional private investment and technology development at scale and at the lowest cost. As an example, the UK *Clean Growth Strategy*[20] released in October 2017 envisages that the low carbon economy (including domestic and global markets for low carbon goods and services) could grow 11% per year between 2015 and 2030[21], four times faster than the projected UK GDP growth over the same period[22].

[17] IEA Hydrogen Implementing Agreement, (2017), op. cit.
[18] Eurostat, (2018), *Environmental economy - employment and growth*, http://ec.europa.eu/eurostat/statistics-explained/pdfscache/41606.pdf (accessed 30.7.2018)
[19] European Commission, (2015), https://ec.europa.eu/energy/sites/ener/files/documents/cop21-brochure-web.pdf (accessed 30.7.2018)
[20] UK Department for Business, Energy & Industrial Strategy, (2017), https://www.gov.uk/government/publications/clean-growth-strategyhttps://www.gov.uk/government/publications/clean-growth-strategy, (accessed 30.7.2018)
[21] Ricardo Energy and Environment for the Committee on Climate Change, (2017), https://www.theccc.org.uk/publication/uk-energy-prices-and-bills-2017-reportsupporting-research/
[22] OECD Long-term GDP forecast https://data.oecd.org/gdp/gdp-long-term-forecast.htm

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Incorporating CCUS into "clean energy" strategies has not been easy, partly because of its perceived risk and cost profile, and partly because it is not an individual technology to be deployed but rather a large-scale infrastructure like water and waste systems[23]. The policy requirements described in the following sections are those considered essential for translating any aspirational objective to deploy large-scale hydrogen and CCUS into enabling government support.

3.4 Policy Requirements

3.4.1 Overview

The need for government policy intervention to deliver large-scale infrastructure investment for the public good is a well-recognised principle[24]. Amongst the risk characteristics of infrastructure development, particularly in the face of new or evolving markets, are:

- long lead times for development and deployment;
- high up-front capital cost;
- long term returns dependent on long duration contracts attempting to deal with uncertainty;
- the risk of stranded assets and/or sub-optimal capacity sizing;
- orchestrated market making/market signals for new infrastructure leading to lack-of-demand risk; and
- financial and structural complexity with multiple public and private sector interfaces.

In the case of CCS infrastructure, the IEA[25] has highlighted that where successful delivery has occurred, the government role has included:

- "strong and sustained government support including policy incentives that adequately address additional capital and operating costs";
- "a requirement or incentive to reduce emissions through emissions performance standards, the imposition of a sector-specific carbon tax or regulatory measure – often in combination with a grant or subsidy"; and
- "A low-risk political, social and regulatory environment for CO_2 storage, including regulatory frameworks to facilitate access to pore space and to manage long-term liability for the stored CO_2".

The policy gap analysis carried out as part of the ELEGANCY WP3 methodology allows for the complexity of policy interactions between different market and business segments and between the needs of the public and private sectors. Figure 3-1 is an example of a policy needs "heat map" based upon the requirements described in the following sections. This figure can be used to summarise the output that arises from application of the policy gap analysis method and tool to any particular case study.

[23] Zero Emissions Platform, (2018), op.cit.
[24] See for example: London School of Economics Growth Commission, (2013), *Investing for Prosperity*, http://www.lse.ac.uk/researchAndExpertise/units/growthCommission/documents/pdf/LSEGC-Report.pdf, (accessed 30.7.2018)
[25] IEA, (2017), op.cit.

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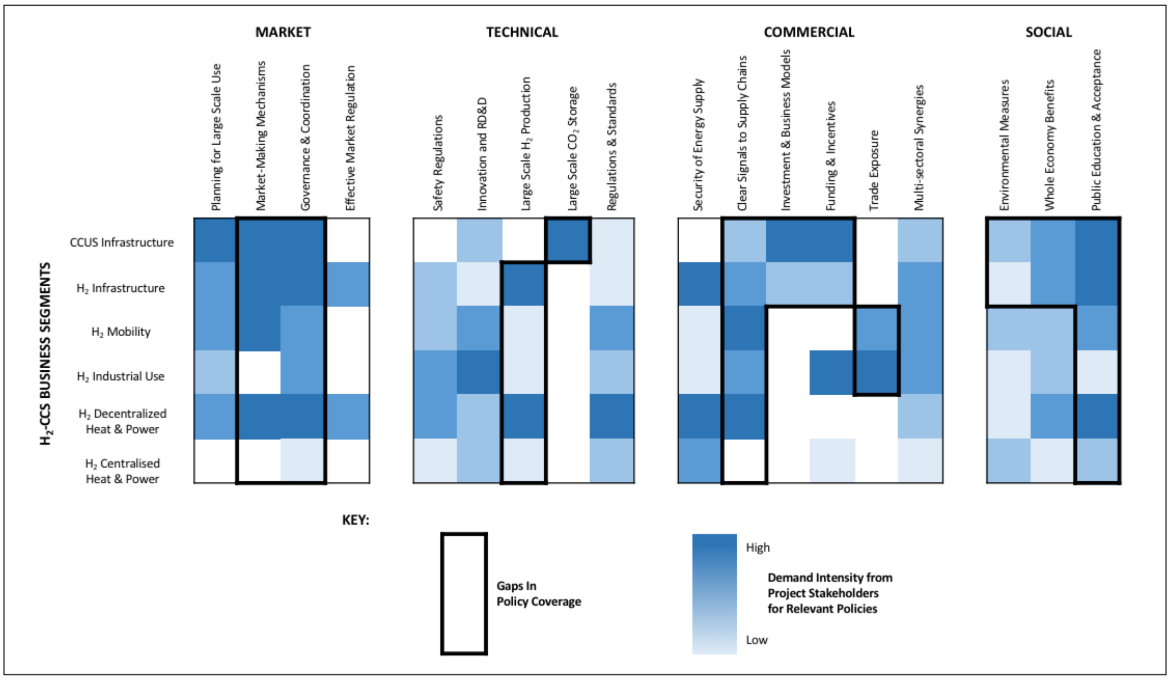

Figure 3-1 Example assessment of policy needs for delivering H_2-CCS business segments (concept adapted from CPI[26])

3.4.2 Policy Needs for Hydrogen Infrastructure

Although the potential exists for future hydrogen infrastructure to look very similar to existing natural gas networks, albeit with some different production, retail and point-of-sale facilities, a number of authors[27][28][29][30] have identified areas of policy that will either need to be developed or modified to assist private sector investment and to overcome the problem of creating sufficient market demand in synchronisation with developing sufficient clean (zero or low emission) production. Particular policy needs for the various hydrogen market sectors are addressed in the sections to follow. This section focuses on the broad policies needed to facilitate the deployment of production and transportation infrastructure.

As discussed earlier, hydrogen is an energy carrier that can be utilised across multiple sectors. Hence policies that recognise the universality of its use are required to bridge the gaps between

[26] Climate Policy Initiative, (2013), *Risk Gaps: A Map of Risk Mitigation Instruments for Clean Investments*, https://climatepolicyinitiative.org/wp-content/uploads/2013/01/Risk-Gaps-A-Map-of-Risk-Mitigation-Instruments-for-Clean-Investments.pdfhttps://climatepolicyinitiative.org/wp-content/uploads/2013/01/Risk-Gaps-A-Map-of-Risk-Mitigation-Instruments-for-Clean-Investments.pdf, (accessed 30.7.2018)

[27] Weidner Ronnefeld, E., et. al., (2016), *CEN - CENELEC Sector Forum Energy Management/Working Group Hydrogen: Final Report*, EUR 27641 EN; 10.2790/66386, https://ec.europa.eu/jrc/en/publication/cen-cenelec-sector-forum-energy-managementworking-group-hydrogen-final-report, (accessed 30.7.2018)

[28] Energy Research Partnership (ERP), (2016), *Potential Role of Hydrogen in the UK Energy System*, http://erpuk.org/project/hydrogen/, (accessed 30.7.2018)

[29] IEA Hydrogen Implementing Agreement, (2015), *Large Scale Hydrogen Delivery Infrastructure*, http://ieahydrogen.org/Activities/Task-28/Task-28-report_final_v2_ECN_12_2_v3.aspx, (accessed 30.7.2018)

[30] Hydrogen Council, (2017), *How hydrogen empowers the energy transition*, http://hydrogencouncil.com/study-how-hydrogen-empowers/, accessed (30.7.2018)

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lack of market pull, novel technologies, and infrastructure deployment at scale. The high priority areas of policy that will help facilitate hydrogen infrastructure deployment include:

1. Removal of market regulatory barriers
   Existing regulations governing electricity and natural gas markets, networks and operators need to be reviewed and modified where necessary to ensure an enabling environment for hydrogen-based activities and the possible interactions with the remainder of the energy system. Regulations need to allow new operations such as transforming power to fuel or power to gas (e.g. production of hydrogen gas via electrolysis of water using electricity from excess renewable generation) and blending hydrogen with natural gas. Hydrogen-based technologies on the cusp of commercialisation need to be able to compete without hindrance from existing regulations that are not fit-for-purpose (for example inappropriate regulated asset returns).
2. Safety regulations
   Regulations that are currently in place for equipment, handling and use of conventional liquid fuels and natural gas require broadening to deal with the specific characteristics of hydrogen. The complete hydrogen value chain from production, safety control and monitoring through transportation and underground storage, to consumer appliances, commercial and industrial equipment, fuel cell vehicles and refuelling stations will need to be covered by new or fit-for-purpose standards and regulations. Development of uniform international technical standards will be necessary. Policies will need to ensure training of tradespeople across a broad spectrum of sectors and activities.
3. Plan for large scale use and transformation
   Hydrogen infrastructure will not be deployable in small and incremental steps such as with onshore wind farms and solar installations. Policies to support delivery will need to ensure a stable investment environment for an extended period of as much as multiple decades and include a commitment to a designed, coordinated build-out and transformation from natural gas to hydrogen. This will mean that a minimum market size will have to be created (for example through city or regional conversion) that can be supported by a no/low regrets scale of production, transmission and distribution infrastructure. Specific market-making policies for different sectors are required and appropriate links between energy producers and end users created.
4. Whole system sustainability criteria for value/benefit metrics
   When governments and treasuries undertake cost/benefit analyses of climate related energy support and investments, it is essential that the basis for evaluating hydrogen-related policies takes account of the synergies and whole-system benefits that hydrogen infrastructure can deliver. The point of a hydrogen economy is to create sustainable, climate friendly energy use across all sectors and hence metrics and evaluation methodologies should reflect this. Individual technology-by-technology, or project-by-project comparisons of investment options will not be valid in this context.
5. Cross sector benefits/synergies and efficiencies
   Further to point 4, climate, energy and economic policies need to target synergies between the different sectors in which hydrogen can be produced and utilised. For example, hydrogen produced from surplus renewable electricity can be used as an energy storage medium. Hydrogen production in industrial clusters can be combined with captured CO_2 to produce other chemicals and fuels, though detailed life-cycle assessments are needed to

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ensure such CO_2 utilisation leads to reduced emissions. Low-pressure hydrogen distribution infrastructure can be used for household heating and strategically located fuel cell electric vehicle refuelling stations. To create the multi-sectoral benefits and cost reductions that come from scale, policies also need to encourage and support cooperation across economic sectors, regions and countries.

6. Hydrogen production
   Targeted policy and financial support for innovation in low emission and clean (green) hydrogen production will be critical to reducing costs and improving efficiency and flexibility. The very high costs of production by electrolysis are not expected to fall to the level of production from steam methane reforming (SMR) or autothermal reforming (ATR) with CCS until at least the 2030 timeframe[31][32]. Hence, a coordinated policy approach to deploying hydrogen infrastructure for a system transformation as described above will also need to be integrated with policies for cost effectively delivering CCS infrastructure and finding synergies between CCS applications.
7. Energy sources and security of supply
   Establishing demand-driven consumer and commercial markets will require new policies that ensure security of supply and prevent distortions in the value chain. Imported quantities of natural gas, hydrogen, or electricity may change in the short term to meet initial market demand and policies will be needed to manage supply risk and price volatility. Whether the feedstock is natural gas in an SMR (or ATR) or renewable electricity in electrolysers, hydrogen producers will not be final consumers and therefore should not be exposed to various duties and other taxes. New incentive mechanisms will be needed for activities such as underground storage and demand management services, new offsets against climate related targets and alternative fuels will have to be considered, new capacity markets created, and a uniform treatment of electricity storage options and services (of which hydrogen becomes one) will be necessary.
8. Clear signals for supply chain/equipment/appliance manufacturers
   The clear and consistent government commitment to a large-scale transformation to hydrogen described above is also essential so that supply chains can develop the requisite skilled workforce and manufacturers of both domestic and commercial/industrial appliances and equipment can invest in the necessary RD&D and production lines that will supply the markets under creation. This of course extends to support for the full spectrum of end user technologies including heat and transport. Innovation support policies for demand-side applications should also be coupled with assistance to develop new export markets in countries where hydrogen is being considered as part of the national energy transition (e.g. Japan, China).
9. Market-pull mechanisms
   Policies that help to establish and consolidate the end use hydrogen markets will be necessary as an adjunct to the targeted hydrogen policies themselves. For example, city air quality pollution limits, vehicle emissions limits, tighter standards on commercial and

[31] Shell Hydrogen report Shell Deutschland and Wuppertal Institute, (2017), Shell Hydrogen Study: Energy of the Future? - Sustainable Mobility through Fuel Cells and H_2, https://www.shell.com/energy-and-innovation/the-energy-future/future-transport/hydrogen.html#vanity-aHR0cHM6Ly93d3cuc2hlbGwuY29tL2h5ZHJvZ2Vu, (accessed 30.7.2018)

[32] Zero Emissions Platform (ZEP), (2017), *Commercial Scale Feasibility of Clean Hydrogen*, http://www.zeroemissionsplatform.eu/library/publication/272-cleanhydrogen.html, (accessed 30.7.2018)

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industrial equipment, burners, and off-grid power generators can contribute to market interest in hydrogen as an alternative. Building regulations can be enhanced to ensure effective measurement of benefits and choices in behind-the-meter applications such as hybrid fuel cell/solar installations and fuel cell combined heat and power (CHP).

10. Public acceptance
    Policies are required that assist the public in understanding the hydrogen economy proposition, the new technologies to be deployed, infrastructure safety, and the consumer benefits across the multiple uses such as domestic heating and cooking, and fuel cell electric vehicles. Central government can work in collaboration with regional and city authorities to develop communication and education strategies that build familiarity and trust in the community.

3.4.3 Policy Needs for CCUS Infrastructure

Like hydrogen, CCS is about large-scale networked infrastructure. Unlike hydrogen, however, CCS is about dealing with an unwanted pollutant and the cost of doing so is not matched by the price society currently puts on the penalty for emitting that pollutant. In Europe, this is the price of carbon allowances in the EU Emissions Trading Scheme (ETS). A large body of literature dealing with European and Member State CCS and CCUS policy exists[33], and many stakeholder organisations like the Carbon Capture and Storage Association (CCSA) and the Zero Emissions Platform (ZEP) have produced material on the policies required to facilitate infrastructure investment and deployment.

For more than a decade CCS in Europe was focussed on low emissions power generation, and EU and national policies were crafted to provide R&D and demonstration funding mechanisms primarily based on competitively awarded grants with the expectation that the price of EU carbon allowances would eventually incentivise the private sector to deploy CCS where it was cost effective. This approach has largely proved ineffective in proving the feasibility of CCS at scale. The outcome of a long list of project cancellations has been a deep understanding by key stakeholders of the policies required to establish CCS as a viable tool in the climate change portfolio.

This section provides a very brief overview of high priority policies needed to deliver CCUS infrastructure. The term CCUS infrastructure is used to cover all the facilities associated with the capture, gathering, transport, distribution and storage of CO_2 whether for direct disposal via geological sequestration or for utilisation either in hydrocarbon fields or feedstock for industrial processes.

1. Strategic plans for large scale use
   In the context of climate mitigation and sustainable economic activity CCUS infrastructure can provide a public service like roads, railways and sewerage systems. Typically, these networks have originally been built and operated by public entities, with the process of planning and delivery backed by central government and treasury. A similar commitment

[33] See for example:
Bellona, http://bellona.org
Carbon Capture and Storage Association (CCSA), http://www.ccsassociation.org
ZEP, http://www.zeroemissionsplatform.eu

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is required by governments at EC, national, regional, and interregional levels to formalise plans and targets in a strategic design supporting deployment of CCUS infrastructure at scales and timing that can satisfy long term climate goals at lowest cost. CCUS stakeholders have already identified no/low regrets capacities and geographies, and supportive fiscal and micro-economic policies are now needed to provide a stable investment environment for an extended period of coordinated build-out with public and private sector participation.

2. CO_2 Utilisation
To a large extent CO_2 utilisation has been divorced from CCS in Europe until recently. Enhanced oil recovery schemes have been evaluated but without the CO_2 availability have not been considered economic or technically feasible, unlike in North America. CO_2 is pumped into greenhouses, but this is a tiny fraction of the emissions mitigation potential of CCS. Research has been conducted into CO_2 utilisation in the chemical industry, including replacing fossil fuel feedstock and producing "renewable fuels" such as methanol. Targeted policies are now needed to increase the utilisation potential in industrial clusters through additional funding schemes, market pull mechanisms (such as end market mandates and incentives), and synergies with other technologies such as hydrogen production and energy storage. Cooperative policies are also required for regional and inter-regional CO_2-source to CO_2-use spatial mapping, linked to CCS cluster developments.

3. Market-making mechanisms and removal of market failures
Hand-in-glove with strategic designs is the need for policies that help to establish and consolidate the markets that will utilise the services of the infrastructure owners/operators. A large body of evidence confirms that CCUS suffers from "missing market" and "co-ordination" market failures. Experience has shown that without organisations mandated and supported to execute CCUS plans and build infrastructure, specifically for the transport and storage elements[34][35], investment cannot take place in the absence of a market. Policies and mechanisms are required to deliver market makers, governance structures, market facilitation regulations, socialisation of costs, and financing and insurance schemes.

4. Business models and commercial structures
Policies are required to support the implementation of novel business models for all or part of the CCUS infrastructure chain that recognise the commercial practicalities of risk sharing, liability handling, operational performance obligations, and the consequences of regulations governing geological storage. Furthermore, these policies need to address the coordination required in the CCUS chain between different public and private entities in the context of the market-making mechanisms described above. Commercial structures such as public private partnerships and regulated asset base businesses used in delivering other infrastructure for the public good will need to be introduced.

5. Whole system criteria for value/benefit metrics

[34] Oxburgh report UK Parliamentary Advisory Group on Carbon Capture and Storage (CCS), (2016), *Lowest Cost Decarbonisation for the UK: The Critical Role of CCS*, http://www.ccsassociation.org/news-and-events/reports-and-publications/parliamentary-advisory-group-on-ccs-report/, (accessed 30.7.2018)
[35] UK CCUS Cost Challenge Taskforce, (2018), *Delivering Clean Growth*, https://www.gov.uk/government/publications/delivering-clean-growth-ccus-cost-challenge-taskforce-report, (accessed 30.7.2018)

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As discussed above with hydrogen, when governments and treasuries undertake cost/benefit analyses of climate related energy support and investments, it is essential that the basis for evaluating CCUS policies takes account of the synergies and whole-system benefits that the infrastructure can provide. Metrics and evaluation methodologies should reflect this at both the macro-economic level (including employment, Gross Value Added (GVA), and export potentials) and at sectoral level. Lifecycle analysis (LCA) guidelines for CCU that facilitate comparison among system options and provide a transparent framework for reporting are required. Individual technology-by-technology, or project-by-project comparisons of investment options or policy choices will not be valid in this context.

6. Cross sector benefits/synergies and efficiencies
   Further to point 5, and analogous to hydrogen infrastructure, climate, energy and economic policies need to target synergies between the different sectors for which CCUS would be a benefit if the carbon price were at a level reflecting the true cost of carbon pollution. This includes hydrogen production in industrial clusters combined with captured CO_2 to produce other chemicals and fuels. Policies are now needed to strengthen the link between CCU and CCS and, as discussed for hydrogen, create synergies that lower infrastructure costs and create a market pull for the infrastructure.
7. Geological storage
   Developed storage capacity is of course the key to enabling activities upstream in the value chain including capture and utilisation. A substantial amount of desktop research has been performed across Europe, storage atlases have been created, and a handful of projects have undertaken real appraisal and development work. Norway has two full-scale offshore CO_2 injection facilities associated with natural gas production. Stronger policies and public sector support are needed to accelerate storage appraisal and development in order to ensure injection capacity is available in time for upstream choices and investments to be made in the potential hydrogen markets, industrial clusters and power sector consistent with the European emissions targets in 2050. Progressing geological storage therefore requires some special treatment in addition to the other policies described in this section. In particular, storage appraisal and subsequent development of strategic storage sites must be decoupled from upstream capture projects, and needs to be carried out as a public good exercise funded by governments, ahead of a market signal either from the ETS or through government mandates. This in turn requires polices to unlock the data held by the oil and gas industry.
8. On-going regulatory review and removal of regulatory barriers
   The principal European regulation governing CO_2 storage (Directive 2009/31/EC) was reviewed for its effectiveness and relevance in 2014 in the absence of substantial practical experience and the ZEP has recommended that it be continuously reviewed every two years[36]. The policies described above for planning, market development, infrastructure deployment, and business models all need complementary regulations to ensure effectiveness and relevance. Harmonisation between jurisdictions for CO_2 transport and storage will be necessary. A host of regulations at EC and Member State level, as well as internationally, need constant review to ensure investment in, and delivery of, CCUS

[36] ZEP, (2017), *Fast Track CO_2 Transport and Storage for Europe*, http://www.zeroemissionsplatform.eu/library/publication/275-fasttracktas.html, (accessed 30.7.2018)

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infrastructure is not disadvantaged. Examples include the ETS, industrial processes, market governance, regulated assets, third party access, capture readiness, hydrocarbon operations (including EOR), health and safety, and state aid/incentive funding.

9. Incentives and innovation
The EU and a number of Member States have provided strong R&D funding support for CCUS technologies and a continuation of these policies at all levels is necessary across the full value chain. Full-scale full chain flagship projects that provide the first infrastructure for future use and expansion need to be funded by governments to meet first injection in the 2020-21 timeframe. At the EC level funding policies and mechanisms need to be reviewed to adapt to, or add, CCUS modalities that enable activities such as pre-FID geological storage exploration and appraisal, feasibility of pipeline and projects of common interest (PCI), CO_2 distribution and aggregation networks, and development of industrial clusters potentially incorporating hydrogen production where appropriate. Incentive and grant schemes need to be in accord with planning and delivery mechanisms as described earlier. Policies are required to incentivise knowledge sharing and technology optimisation. Incentives to encourage oil and gas exploration and production operators to preserve valuable knowledge, data and infrastructure for re-use are essential, and joint public and privates sector schemes to enable delayed decommissioning and re-use need to be developed.
10. Public acceptance
In general CCS has not been well received across Europe by the public; in part because of its association with fossil fuels and in part due to a fear of leakage or induced seismicity from underground storage sites. In those areas/regions more familiar with industrial facilities and hydrocarbon operations, public acceptance has tended to be higher, particularly if geological storage operations are planned to take place offshore. Again, as in the case of hydrogen, policies are required that assist the public in understanding the CCUS climate proposition, the new technologies and products it facilitates (including hydrogen), infrastructure safety, and the economic benefits it delivers. Central government can work in collaboration with regional and city authorities to develop communication and education strategies that build familiarity and trust in the community.

3.4.4 Policy Needs for Hydrogen Markets

The policy needs described in section 3.4.2 for hydrogen infrastructure are of course crosscutting for the various possible end-use markets. This section summarises some of the sector specific policy needs that will help to deliver new technologies and growing market demand in the event that large-scale low emissions production of hydrogen can be achieved. There is an overall system-level policy need to ensure integration and positive feedbacks between policies that deliver infrastructure and policies that encourage market take-up of hydrogen within the potential markets.

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3.4.4.1 Low/No Emissions Heat

Achieving a roll-out of hydrogen for domestic, commercial and industrial heating markets will require policies for the following[37][38][39][40]:

1. Establish national and regional market governance frameworks that match the specific challenges of heat decarbonisation;
2. National and regional bodies allocated responsibilities for delivery and mandated to undertake planning, installation and conversion of appliances;
3. Long term national and regional infrastructure programmes that enable planned delivery and market development over suitable timeframes;
4. Ensure building regulations and energy efficiency support schemes are fit-for purpose for using hydrogen in heating;
5. Establish product standards so new gas appliances are manufactured dual-fuel and hydrogen ready;
6. Establish safety standards for the use of hydrogen as a domestic fuel;
7. Maintain options for heat decarbonisation and synergies between various technologies to ensure minimal disruption, cost efficiencies for local and regional authorities and behind the meter consumer choice;
8. Heat decarbonisation strategy should be integrated with industrial strategy, which should include industrial use as well as equipment and appliance manufacture and export;
9. National, regional and local communication plans providing understanding and preparation for consumers to accept and support natural gas to hydrogen conversion.

3.4.4.2 Low/No Emissions Mobility

Achieving a market for hydrogen use in domestic and commercial vehicle transport and other mobility applications such as rail and marine will require policies for the following[41][42][43]:

1. Policy coordination at national, regional and European levels for low/no emissions mobility (climate-based mandates, obligations and benefits), including hydrogen fuel cells for stationary as well as mobility applications;
2. Long term national and regional infrastructure programmes including hydrogen refuelling station (HRS) networks that incorporate matching of hydrogen availability and market development over suitable timeframes;
3. Establish national and regional market governance frameworks and mandated organisations that enable co-ordination of national deployments (station location, timing etc.) facilitated by a sustainable funding strategy;

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[37] European Commission, (2016), *An EU Strategy on Heating and Cooling*, COM(2016) 51 final, https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf, (accessed 30.7.2018)
[38] Weidner Ronnefeld, E., et. al., (2016), op.cit.
[39] MacLean, K., et. al., (2016), *Managing Heat System Decarbonisation: Comparing the impacts and costs of transitions in heat infrastructure*, Imperial College Centre for Energy Policy and Technology
[40] Energy Research Partnership (ERP), (2017), *The Transition to Low-Carbon Heat*, http://erpuk.org/project/low-carbon-heat/, (accessed 30.7.2018)
[41] European Commission, (2016), *A European Strategy for Low-Emission Mobility*, COM(2016) 501 final, https://ec.europa.eu/transport/sites/transport/files/themes/strategies/news/doc/2016-07-20-decarbonisation/com%282016%29501_en.pdf, (accessed 30.7.2018)
[42] Weidner Ronnefeld, E., et. al., (2016), op. cit.
[43] Shell Deutschland and Wuppertal Institute, (2017), op. cit.

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4. Government supported early phase with funding assistance (e.g. subsidies, tax rebates) that creates the beginnings of a HRS network in strategic locations enabling initial fuel cell electric vehicle sales;
5. Early sales of domestic vehicles and buses to be enabled by public sector use and procurement programmes;
6. Increasingly stringent emissions regulations for vehicle use within city limits;
7. Establish or complete national and European programmes for regulations and standards (fuel, handling, transport, storage tanks, refuelling stations, hydrogen fuel cells (HFC), vehicle, rail, marine), permitting, licensing, and certification;
8. R&D funding for the continuing development of hydrogen-based technologies for trucks, articulated vehicles, rail, ships, and aircraft;
9. Hydrogen for mobility strategy should be integrated with industrial strategy to include vehicle and fuel cell manufacture and export;
10. National, regional and local communication plans providing understanding and preparation for consumers to accept and support FCEVs and refuelling networks.

3.4.4.3 Power

Hydrogen can be used in different ways for electricity generation: large stationary power and CHP from gas turbines with H_2-blended gas mixes, and small or micro stationary power and CHP using hydrogen fuel cells. The principal policy needs to support hydrogen for power or CHP uses are[44]:
1. R&D funding for continuing technology development and demonstration;
2. Regulations and incentives (e.g. exemptions from grid connection fees) to encourage deployment and market growth, particularly in off-grid situations and for security of supply in large and small-scale power backup systems for emergency and uninterruptible power supplies;
3. Policy coordination at national, regional and pan-European levels for integrating hydrogen power generation with renewable power generation;
4. On-going review and improvement of national and international technical standards for hydrogen use in power generation;
5. Communication strategies to consumers for market development of micro-CHP or mini-CHP applications in the domestic and commercial sectors.

3.4.4.4 Industry

A market already exists for the industrial use of hydrogen as a feedstock in refineries and chemical plants to produce ammonia and methanol. Emissions reduction efforts, increasingly stringent fuel quality standards, and end-user markets for liquid fuels and chemicals produced not from petroleum feedstock, but from low cost CO_2, biogas, syngas, and other sources of carbon will help to expand hydrogen use in industry. Furthermore, lower emissions steel-making processes based on hydrogen reduction rather than natural gas or gasified coal offer potential. Policy needs for hydrogen in industry include:
1. Policy coordination at national, regional and pan-European levels for hydrogen use in industry recognising the impact of end-use markets on industrial assets and products;

[44] See for example: Weidner Ronnefeld, E., et. al., (2016), op. cit.

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2. Long term national and regional infrastructure programmes including hydrogen production and CCS that are integrated with industrial strategy;
3. Support trade exposed industries to develop new products with low lifecycle emissions without losing competitiveness in domestic and international markets;
4. R&D funding for the continuing development of hydrogen use in industry;
5. National, regional and local communication plans providing understanding and preparation for consumers to accept and support HFC electric vehicles and refuelling networks.

3.5 European Union and Country Policies

European Union and case study country policies relevant to the funding of innovation and support for development of hydrogen-CCS markets and infrastructure as of the date of writing are summarised in Appendices B-G.

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4 DEFINING INVESTMENT BARRIERS AND INVESTMENT RISKS

4.1 Summary

The first steps of the business model selection and development methodology focused on the relevant business background assessment (legal and regulatory, macro-economic and fiscal, market and public policy) using a simple suite of tools based on heat maps. This initial exercise allows the gathering of critical factors predominantly outside the control of the private developers/investors which traditionally exert a significant influence on their real and perceived investment risks. The following chapters will focus on step 3 of the methodology, i.e the identification and mitigation of the major business and investment risks and investment barriers that impact the investment attractiveness and expected rate of return for each of the market sectors and business opportunities from both a public and a private sector perspective.

This chapter will present and discuss the concepts and differences between business risks and investment barriers, catalogue and categorise typical and relevant investment risks and barriers for H_2-CCS infrastructure investment. Chapter 5 and Chapter 6 will focus on the options available to address investment barriers and business risks respectively.

4.2 What are Investment Risks and Barriers?

Investment risks can be defined as the potential of an event having negative impact on the investment outcome (as a combination of likelihood and severity of the event), which can be defined in terms of investment/business profitability, reputation, etc., from a private investor perspective or poor social/economic/environmental benefits from a public investor perspective. Investors, whether private or public, analyse their risks to achieve specific outcomes in order to make decisions on their investment choices and expected rates of return compared with alternative options. The level of risk whether real or perceived by the potential investors determines whether large infrastructure projects can attract sufficient private capital at an acceptable rate of return for both the private and public parties. In addition, as explained earlier, undermanagement of risks and risk allocation throughout the life cycle of the project is the main cause of poor outcome of private/public partnership infrastructure investment.

Investment barriers are actual circumstances/external conditions that have a major influence on the quantification of specific investment risks by the potential investors and for which there are no risk mitigation measures available in the market and therefore require a tailored intervention by the government in order to attract private investment. The investment barriers result in those risks being considered excessive or beyond their control by the potential investors and therefore prevent investment in the project/business sector. It is critical to identify and understand early the major investment risks and underlying barriers for investment.

Risk allocation in green infrastructure investments between the private and public parties determines the level of risk carried by each based on the ability of the parties to mitigate the risks and control the outcomes. Good risk allocation should allocate the risks to the parties best suited to take them. In this report, we will use the risk allocation framework used by the Climate Policy

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Initiative[45] based on the OECD risk sharing model for public private partnerships[46] in which risks are defined as being either endogenous or exogenous with the following definitions:

- "Endogenous risks are risks which the project developer or sponsor has a certain extent of control over and can directly manage in order to influence the actual outcome (e.g. technology, management of financial resources);
- Exogenous risks are risks which the project developer has neither control over, nor ability to mitigate (e.g. political risks, adverse changes in national policies, currency devaluation) and are better managed by the public actor."

Sustainable Decisions Limited created a "Risk Assessment Tool" presented in Appendix A.2. to carry out a preliminary assessment of the investability barriers and major business risks in each of the market sectors/business opportunities of a specific case study and to generate the risk matrix for a given case study.

4.3 Investment Risks

Investment Risks can be classified subjectively in many different ways. For the purpose of WP3 and our methodology, we have decided to use the classification used by the Climate Policy Initiative[47] and based on the OECD risk sharing model[48]. The four categories of risks are presented in *Figure 4-1 Risk Classification (after CPI)* and the types of risks for each of these categories are illustrated in *Table 4-1 Risk Categories and Types (after CPI)*.

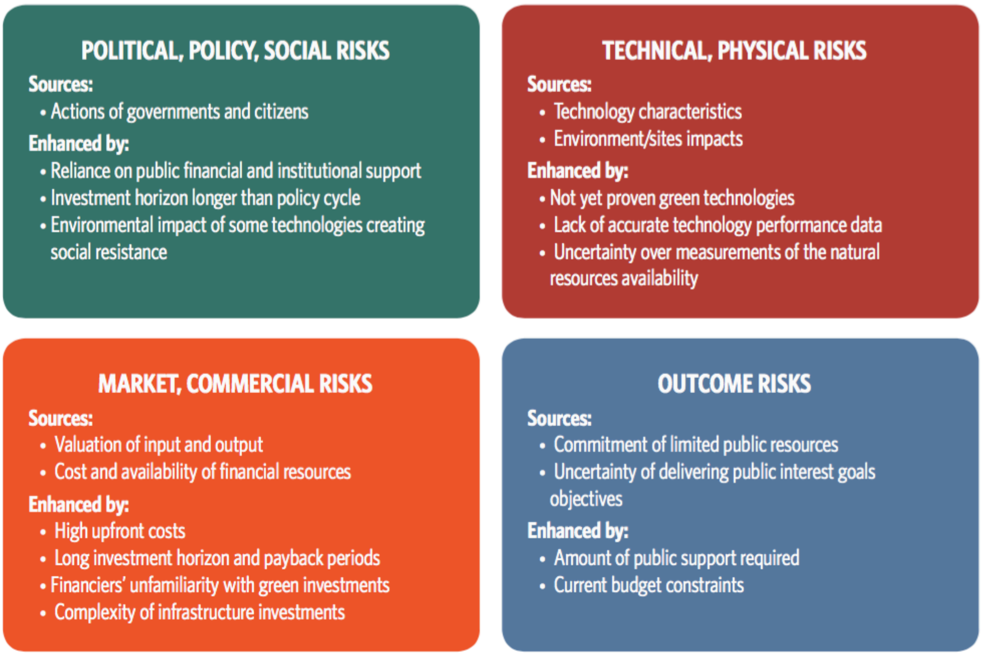

Figure 4-1 Risk Classification (after CPI[49])

[45] CPI, (2013), op. cit.

[46] OECD, (2008), *Public-Private Partnerships: In Pursuit Of Risk Sharing And Value For Money*, http://www.oecd.org/gov/budgeting/public-privatepartnershipsinpursuitofrisksharingandvalueformoney.htm, (accessed 30.7.2018)

[47] CPI, (2013), op. cit.

[48] OECD (2008), op. cit.

[49] CPI, (2013), op. cit.

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Table 4-1 Risk Categories and Types (after CPI)

Risk Category	Risk Type
Political, policy, and social risks These risks derive from both the legitimate actions of authorities exercising their legislative functions in the interest of the public (policy/regulatory risks), and illegitimate and discriminatory acts by authorities and citizens, and political violence and instability.	Regulatory risk: changes to standards, third party access regulations, etc
	Policy risks: changes to tariffs/subsidies or other commercial/financial incentives or failure to implement agreed tariff increases (to protect customers and avoid social unrest)
	Legal and Ownership rights: expropriation or nationalization of project assets, unreliability of legal system, etc
	Permitting and Consenting risks: delays, changes, unacceptable permit conditions, etc
	Social risks: from opposition to project by private individuals to large communities to social unrest and political violence.
	Political and Governance risks: corruption and bribery, procurement, discriminatory treatment, repeal of contracts, project cancellation, trapped in-country capital, etc
Technical and Physical risks These risks derive from the physical characteristics of the assets and/ or the surrounding environment.	Construction risks: cost overruns, delays, technology underperformance
	Operational risks: performance, reliability and availability,
	Output risk: strong risk of product unavailability (H_2 supply for H_2 markets, CO_2 supply for CO_2 transportation and storage business)
	Environmental risks: unforeseen costs of operational compliance, clean up liabilities from incidents, etc
	Decommissioning risks: timing (earlier than anticipated), cost (higher costs than anticipated), reputation (public opposition)
Market and Commercial Risks These risks derive from the action of markets and commercial counterparties, the economic value of the output (price, volume) and the financial dimension (cost and availability of capital, liquidity)	Currency and exchange risks
	Market/Demand risks (uncertainty of revenue): uncertainty on volume, risks of infrastructure oversizing, uncertainty on market pricing (carbon pricing, commodity pricing, etc)
	Financing risks: availability and cost of capital, term, liquidity for refinancing

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Risk Category	Risk Type
	Counterparty risks: risk of default of contractual counterparties on payments and performance obligations
	Exit/Liquidity risks: inability to monetize investment value prior to the end of the life of the assets for equity and debt investors as well as public investors.
Outcome Risks These risks relate to the ability of the project(s) to deliver the desired outcomes for the public for a given budget	Emission Reduction: failure to deliver emission reduction expected prior to project execution OR emission reductions sufficient in comparison to competing technologies that have become available in parallel.
	Co-impact risks: risks of under delivery of indirect outcomes such as social, health and economic benefits (employment, social regeneration, tax revenue, improved air quality, etc)
	Budget Impact risks: risks of cost overruns and financial resources required exceed budget available
	"White Elephant" risk: risk of overall underperformance of asset in comparison to competing green technologies and over investment due to oversizing. Asset is "stranded".

4.4 Investment Barriers

The section illustrates the investment barriers by providing a number of typical barriers for green infrastructure investment and includes the well documented barriers for CCS infrastructure investment). Examples of the potential impact that these investment barriers have on a number of risks are also provided. Please note that this is not an exhaustive list of barriers – these are case study specific. The IEA has highlighted a number of key CCS specific barriers to investment in their report *Five Keys to Unlock CCS*[50]

[50] [50] IEA, (2017), *Five keys to unlock CCS investment*, https://www.iea.org/media/topics/ccs/5KeysUnlockCCS.PDF, (accessed 30.7.2018)

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4.4.1 Examples of Investment Barriers

Table 4-2 Example barriers to investment

Risk Category	Investment Barrier	Potential Impact
Political, Social and Policy Risks	Strong political instability	Impact on multiple risks: currency inflation, tariff/subsidy changes,
	Lack of confidence in policies / historical record of policy volatility (e.g. subsidy removal)	Impact on risk of tariff change.
	Prescriptive and inflexible infrastructure/energy programme requirements	Risk of loss of development expenditure if project cannot proceed.
	Unstable regulatory settings/political interference	Risks of time/financial loss during project development, risks of policy changes during operation.
	Community opposition	Impact on permitting and consenting, reputational risks
	Lack of established and reliable consenting regime and decision framework in local vs national issues	Impact on planning/consenting risks
	Poor public governance, corruption and lack of transparency	Ethical and reputational risks, risk of repeal of contracts
Technical and Physical Risks	EU ETS liability (see next section)	Risk of underperformance of CO_2 capture/storage is impacted by liability under EU ETS and uncertainty of emissions prices
	EU CCS Directive: decommissioning and monitoring requirements and liability (see next section)	Financial impact on profitability and risk of unlimited liability post decommissioning
	Uncertainty of CO2 storage rates and injectivity	Risk of underperformance
	Lack of commercial CO_2 storage options – contingency in case of technical issues	Risk of underperformance of reservoir is impacted by lack of back up/contingency options and cost of development
	Lack of appliance standards	
	Unproven technology (at scale)	Impact on construction, operational and reputational risks, etc
Market and Commercial Risks	Direct interdependencies - cross chain default/ market coordination failures	Impact on risk of payment default and loss of main revenue stream(s)
	Lack of market signal/incentive for conversion to hydrogen	Risk of unprofitability: risk of demand and revenue being insufficient
	Lack of commercial driver for industrial CO2 emission reduction	
	Lack of pricing framework (regulated transport)	
	Insurance market limitations for CO_2 transport and storage	Risk of financial loss from CO_2 leakage too high in case of technical/geological failure

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Risk Category	Investment Barrier	Potential Impact
	Underdeveloped local currency markets	Financial risk
	Lack of appropriate financial instruments and capital market (structural and conjectural, i.e. financial crisis)	Liquidity risk and impact on cost of capital and profitability
	In country dispute and arbitration process	Risk of major loss of assets / loss of revenue and impact on financeability
	EU CCS Directive and financial securities related to CO2 storage permit (see next section)	Impact on profitability and liability profile

4.4.2 Legal Liability in CO_2 Storage: A Crucial Barrier

In Europe both private and public organisations have struggled to make investment cases in the face of the legal liability associated with CO_2 storage. The regulatory framework under the EU CCS Directive[51] identifies a number of liabilities for operators of sites for the permanent geological storage of CO_2. It is normal to divide liability into three periods under the EU CCS directive:

I. operation,
II. post-closure prior to liability-transfer
III. and post-closure post-transfer.

Prior to starting injection under a storage permit, an operator needs to demonstrate having a financial security in place[52], to safeguard that the operator can financially carry the liabilities the operator is subject to. The operator is subject to something close to a strict liability, requiring the operator to monitor the storage site in order to detect irregularities, migration, leakage and significant adverse effects[53], report to the competent authorities[54] and initiate and pay for necessary measures in case of leakage and significant irregularities[55]. Further, the operator will be liable for submitting allowances in case of leakage.

After the injection stops, the CCS Directive requires the operator to close and seal the storage site and remove the injection facilities. The operator will continue being liable for monitoring, corrective measures and surrender allowances for a period of 20 years post-closure, unless a shorter period is agreed with the competent authority. After 20 years, the liability shall be transferred back to the public authorities, provided that the operator can demonstrate that the stored

[51] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide
[52] CCS Directive Article 19
[53] CCS Directive Article 13
[54] CCS Directive Article 14
[55] CCS Directive Article 16

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CO_2 is "completely and permanently contained"[56] and that there is a financial mechanism in place to replace the financial security[57].

Under the CCS Directive liability for stored CO_2 therefore evolves for both the authorities and the operator throughout the lifetime of a permit, and eventually shifts towards transfer of liability back from the operator to the authorities. There is always some liability or risk for liability throughout the entire life of a storage project for both public and private parties[58]. Even though a storage permit will submit the operator to a form of strict liability, the authorities risk carrying the liability for unwanted events such as clean-up and mitigation of leakage or damage in a situation where, for example, the operator faces bankruptcy or if there has been granted a permit with a form of cap on the final liability for the operator.

This is in line with the authorities' liability under public international law, which first and foremost deals with the states' responsibility and liability towards each other and the world as a whole. The authorities cannot look the other way if an operator is not doing what is required. This also follows directly from the wording in the Directive. Also, after transfer, the authorities are not 100 % liable for the project. The financial mechanism required prior to transfer is meant to cover most of the authorities' expenses and liabilities. Also, there is a claw-back option if the operator has acted negligently or with fault prior to transfer[59]. However, it is important to emphasise that the claw-back only applies in cases of neglect or fault. If, for example, an earth quake should trigger a leakage which cost more to mitigate than what is covered by the financial mechanism, the authorities may not go back to the operator for increased funds or reimbursement.

4.5 Risk Allocation – Essential Principles and Main Actors[60][61]

Following on the previous step of identification of major investment risks and understanding of any specific investment barriers, it is essential to consider the concept of risk allocation. Risk allocation is at the centre of every infrastructure development involving private and public finances. The appropriate application of risk allocation principles determines not only the attractiveness for equity, debt and government investors of a given project (acceptable rate of return, financeability) by ensuring the risks are allocated to the parties best placed to bear them, but also whether it will able to remain viable though to the end of a long-term contract.

The central tenants are:

- risks should be allocated to the parties best suited to manage them and at the lowest cost;
- risk allocation should consider not only who is the best party to management the occurrence of the risk but also the outcome of the risk (and its ultimate cost);
- risk allocation should be informed by market conditions

[56] CCS Directive Article 18
[57] CCS Directive Article 20
[58] See also: Havercroft, I. and Macrory, R., (2014), *Legal Liability and Carbon Capture and Storage: A Comparative Perspective*, Global CCS Institute
[59] CCS Directive Article 18, 7th paragraph
[60] See also: Hovy, P., (2015), *Allocation in Public-Private Partnerships: Maximizing value for money*, International Institute for Sustainable Development, https://www.iisd.org/sites/default/files/publications/risk-allocation-ppp-maximizing-value-for-money-discussion-paper.pdf
[61] See also: Climate Policy Initiative, (2013), op.cit.

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The main actors are:

- Public Sector
  - Directly through government body, commercial entity, counterparty authority;
  - Indirectly through multilateral agencies (e.g. world bank, EBRD, ADB, EIB), export/import bank and export credit Agencies (ECAs).

- Private Sector
  - Financial market players offering de-risking instruments such as currency swaps, interest rates swaps, and other derivative and hedging instruments;
  - Debt Providers: commercial banks, bond market (pension funds, insurance funds…),…
  - Equity investors: in a number of forms and funding structures from balance sheet, limited recourse project finance, joint ventures and public/private partnerships
  - Contractors, sub-contractors, and private companies in the supply chain
  - Insurers: standard and bespoke insurance companies

The risk allocation framework depicted in *Figure 4-2* was developed by the Climate Policy Initiative and builds upon the OECD risk sharing model for public-private partnerships[62]. Exogenous risks such as political, policy, social risks and outcome risks are generally difficult to manage for private parties who have limited control over their occurrence and their impact and better allocated to the public sector. Endogenous risks such as market and commercial risks and technical and physical risks are general better to be borne by the private sector. However, these principles are flexible and need to adapt to the project circumstances. For example, the technical risks of performance uncertainty on new green investments combined with the lack of historical data may be better pooled between public and private sector (e.g CO_2 storage risks). The lack of market liquidity due to structural and conjectural factors may require the involvement of the government (directly or indirectly through agencies).

[62] OECD (2008), *op. cit*

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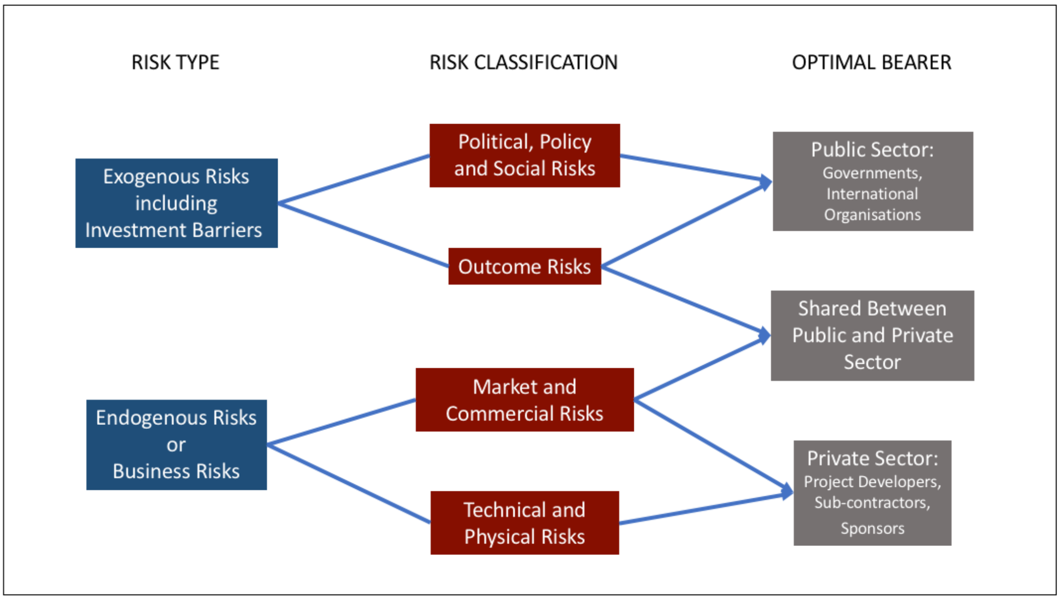

Figure 4-2 Risk allocation framework (after CPI[63])

Risk allocation and the concept of incentives go hand in hand. In practice, governments provide "incentives" to the private sector to facilitate the mitigation of risk or to overcome an investment barrier. Hence, we consider incentives are mechanisms that encourage:

- participation/collaboration (political and social mandate);
- investment (overcoming barriers);
- re-use infrastructure/facilities (avoid/delay de-commissioning);
- to operate (including construction and storage site post-closure stewardship); and
- to remediate (catastrophic events, environment, safety).

In the WP3 methodology we do not focus on "incentives" as a separate device to risk and barrier mitigation mechanisms.

[63] CPI, (2013), op. cit.

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5 ADDRESSING INVESTMENT BARRIERS

5.1 Role of government

Investment in new H_2-CCS infrastructure and creation of new low carbon energy markets are high risk, long term, capital intensive type of investments. They create long life cycle assets with high sunk costs where there is a significant gap between average and marginal costs resulting in high inherent revenue uncertainty risks especially with the possibility of technical obsolescence from technological improvement. In addition, as was presented in Chapter 4, there are specific investment barriers for H_2-CCS chains

Tailored government intervention is needed to address generic and specific investment barriers for the relevant local conditions and mitigate/re-allocate the associated exogeneous investment risks that cannot be underwritten by insurance, or commercial arrangements between private equity and/or debt investors.

5.1.1 Instrument Types for Government Intervention

The government has access to a wide range of types of instruments to achieve desired policy outcomes. These instruments do not only serve to remove investment barriers but also to deliver value for money for the public by influencing the actual and perceived risk profiles of the investment and therefore the rates of return earned on private investment and by helping markets function effectively[64] (see Table 5-1).

Table 5-1 Main types of government instruments for intervening in market and infrastructure development

Instrument Type	Subcategories/Examples
Policy and Market Signals	Policy commitments, targets and carbon budgets
	Principles for evaluating investment – (social economic benefits)
	Decision-making structure
Regulation and Influence Direct regulation covers a wide range of government actions, from primary legislation setting market frameworks through to detailed sectoral regulations Influencing avoids use of direct regulation to direct desired outcomes	Price and volume regulations (including direct constraints on entry into the market)
	Regulations on product characteristics, standards or quality
	Financial and Accounting regulations
	Influencing consumers through education, information, taxation

[64] Office of Fair Trading, (2009), Governments in markets – why competition matters – a guide for policy makers, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/284451/OFT1113.pdf, (accessed 30.7.2018)

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Instrument Type	Subcategories/Examples
	Influencing private sector: encouraging self-regulation (e.g. code of conduct), sharing of information to coordinate private sector activity to invest to create market
Direct and indirect financial support (note: consideration of State Aid limitations)	Financial support (through direct use of public resources) – i.e capital grants, subsidies, taxation
	Direct funding (through indirect use of public resources) – i.e. co-investment through equity and/or debt
	Financial (unfunded) support – i.e public guarantees, back up liquidity facility, etc
Market Making Role of government as market designer and supervisor rather than regulator or provider	Introduction of competition to increase user choice
	Tradeable permits – creation of market for tradeable permits such as EU ETS and CO_2 market
	Competitive Tendering - public procurement through competition to deliver products/services
Provider	Government as direct provider of goods/services – for example for social reasons such as National Health Service in the UK

However, it is also important to recognise that such dependence on government intervention adds another type of risk for private investors and decision-making biases which also need to be addressed. Governments become the ultimate guarantor of the contracts which allow the investors to earn a return, they control the planning process, they define the methodology to evaluate the investment options from the public's perspective (different in each country and subject to political bias – e.g. UK Treasury Green Book) which support the policy choices.

5.1.2 Tailoring interventions for market maturity – from macro-economic intervention to micro-economic intervention

Government intervention also needs to be tailored and evolve with the advancement of the markets and infrastructure development. Policies and incentives to create and facilitate the initial investment in new infrastructure and new markets will be different from those required to maintain a viable business on an ongoing basis into the future. In the early stages of new infrastructure build and market creation, there is a strong need for engagement between private and public stakeholders to develop a suitable package of intervention at the macro-economic level that is coherent and forward looking. This is needed in order to attract private investment and create a long-term shift in energy landscape at a suitable cost to the public. Governments need to create the investment framework with a clear policy direction (and stability), basic structure, rules and regulations and appropriate tailored interventions to address the market failures and investment barriers

As the sector matures, the objectives of the government shift from attracting the first investors to encouraging further build out of infrastructure, accelerating market growth, multiplying market investments and the entrance of market players to introduce greater market competition. The

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public intervention needs to transition to more private market mechanisms: government mandates and agreements with private investors are replaced by commercial agreements between private entities, the level of subsidies or other financial support and market regulation is adjusted, ownership of assets by the government is reviewed and reduced as relevant.

5.1.3 Tailoring interventions for each business sector

The package of government intervention needs to be tailored for each business sector of the H_2-CCS chain, for the investor types, the investment risk profiles and specific investment barriers considering the history of similar markets in-country or internationally, and the existing regulations and constraints.

As an example, *Figure 5-1* below illustrates a range of tailored policies and incentives which has proven effective in supporting CCS in various jurisdictions outside Europe, including policies targeted at different parts of the CCS value chain and across the project life cycle. In the case of the CO_2 storage business sector, interventions need to address the significant early stage at-risk cost for exploration and appraisal activities, the late stage post-closure measurement, monitoring, measuring and verification compliance costs, and the long-term leakage liability. Solutions include 100% tax deductibility on exploration activities, caps on MMV costs in the post-closure period prior to hand over, financial security caps and agreed liability transfer to government for the final closure. Some of these solutions may also apply to a seasonal H_2 storage business

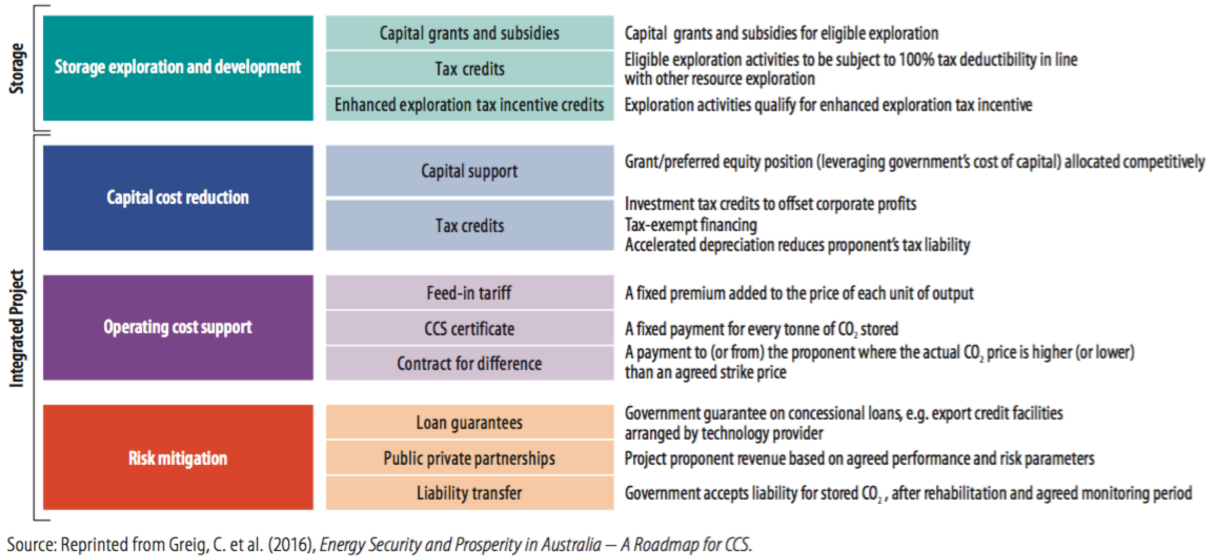

Figure 5-1 Policy Incentives for CCS

5.2 Government Measures to Remove Investment Barriers

5.2.1 Typical Government Measures

This section presents a list of government measures for illustrative purposes to support the case study teams in their case study development and discussions with private and public entities. It is not intended to be an exhaustive list of measures and it is expected that applying the methodology will lead to selecting and creating the right package of measures for a given project in the specific country environment.

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Table 5-2 Government measures available for removal of investment barriers for H_2-CCS

Instrument Type	Government Measure
Policy and Market Signals	• Public commitment to support the relevant green investment over the long term supported by firm budget announcements • Setting long term visibility and transparency on policy direction through multi-year, cross party frameworks • Clear government mandates
Regulation and Influencing	• Creation of regulatory body (creation of new agency, combination of existing regulatory agencies with extended remit, or mandated coordination of multiple agencies) • Structural changes to create institutional architecture to govern infrastructure strategy, delivery and finance • Intervention at national and EU level to amend regulations, i.e. licensing requirements under OGA for re-use of infrastructure • Regulatory exemptions – for example, exemption from offshore licence requirements to decommission within a certain period of time, exemption from standard permitting process (e.g. fast track as with EU PCIs), or market such as UK RIIO type mechanisms
Direct Financial Support Assistance with direct impact on public resource – subsidising the private sector with contributions or grants reduce the private commitment or increase economic return of an otherwise unprofitable project	• Umbrella and implementation agreements • Capital grants and subsidies • Revenue support mechanisms such as feed-in-tariffs, contracts for difference, CO_2 (storage) certificates, other tradeable permits • Tax credits and other tax incentives (specific note for re-use of infrastructure/mothballing) • Tax-exempt finance • Accelerated depreciation • Interest rate subsidies • Re-use incentive mechanisms including financial support for mothballing, assistance to transfer liability away from production JVs e.g. buy-out of liability or equity transfer to state • Network incentives included in the rate of return of the regulated system operator
Indirect Financial Support – Unfunded Options Generally, credit enhancement instruments provided through multilateral institutions, export credit agencies, national development banks or public sponsored infrastructure funds to an infrastructure's creditors to overcome structural problems	• Government loan and credit guarantees (e.g UK Guarantee Scheme) • Government underwriting – capex, opex, revenue • Financial security caps • Government warranty • Government backed concessional loans • Dedicated government backed private equity funds
Indirect Financial Support – Funded Options ownership structuring with involvement of government of other institutions (see above)	• Co-investment as equity and/or debt • Capital structures including public-private partnerships, government ownerships… • Creating targeted funds with cornerstone public funding to address specific market failures: dedicated government backed private equity funds, international climate funds

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Instrument Type	Government Measure
Market Making	• Procurement Competition (e.g UK CCS Competition) • Targeted government procurement (public sector purchase agreements) • Carbon Markets (see detail in section 5.3 below)
Provider	• CO_2 transportation and storage – 100% owned government company (in early years)

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5.2.2 Assessed Principal Investment Barriers for Case Study Countries

Table 5-3 below presents a peer-reviewed list of principal investment barriers applicable to ELEGANCY case study countries together with examples of possible measures to remove or mitigate the barriers within those jurisdictions.

Table 5-3 Principal investment barriers in ELEGANCY case study countries

H_2-CCS Investment Barrier	Possible Mitigation Measures
Missing market for CO_2 transport and storage services	• Government underwriting the provision of affordable service to CO2 emitters • Creating end use markets that can socialise and regulate the additional cost of clean energy and products e.g. Hydrogen for heat or transport • CO2 emitter obligation plus mechanism for import/export competitiveness adjustment • Appropriate short and long-term price for CO2 as environmental pollutant via e.g. carbon market, carbon tax
Dependence of investment case on stable government policy and coordinated delivery of infrastructure/utilisation	• Parliament commitment to first infrastructure in statute with binding mandate and budget given to an appropriate public authority • Implementation agreements split between emitters and the CCS chain with government providing State mandates and assurances to enable financing
Uninsurable long-term leakage liabilities defined in EU Directive and national regulations with large front-loaded Financial Security	• State owned transport and storage operator with no private sector involvement other than technology supplier with guarantees and warranties • State owned transport and storage company accepting liabilities with private sector operator as contractor to state having capped guarantees and warranties • Joint public-private transport and storage company with private partner liability capping and government underwriting of liabilities above agreed level • Private sector transport and storage company based on agreed risk sharing principles (e.g. defined events, defined volume and carbon price collar) with liability capping and government underwriting beyond cap
Guaranteed intra-chain counterparty performance is required between CO2 producer/capturer and CO2 capturer/gatherer/transporter (+storer)	• Utilise a binding umbrella agreement that guarantees intra-chain counterparty performance with government providing state step-in, guarantor of last resort, assurances and underwriting as required
Uncertain global commitment to pace and evolution of low carbon or circular economy matching climate targets	• Strengthened EU and Member State policies to credibly deliver mid-century emissions targets at low cost and maximum macro-economic benefit
Poor or inconsistent public acceptance of utilisation of CCS technologies and chain for decarbonisation	• Long term proactive education, communication and engagement plan and actions • Promotion and development of socio-economic and environmental benefits

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5.3 Carbon Markets

5.3.1 Overview of carbon pricing policy instruments

Putting a price on carbon has become one of the priorities of policymakers around the world when it comes to bringing down greenhouse gas emissions and driving investment in cleaner technologies. The World Bank[65] lists several characteristics and advantages of carbon pricing over the more classic "command and control" instruments such as mandatory emission limits. Indeed, carbon pricing:

- captures the external costs of carbon emissions and ties them to their sources through a price on carbon;
- shifts the burden for the damage back to those who are responsible for it and can reduce it;
- provides an economic signal;
- gives polluters a choice between halting or reducing their polluting activity, and continuing to pollute and pay for it; and
- ensures overall environmental goals are achieved in the most flexible and least-expensive way to society.

There are two principal types of carbon pricing: carbon taxes and cap and trade systems. A third mechanism is carbon offsetting, which can be used in combination with the two aforementioned types of carbon pricing. A fourth type, voluntary approaches that put a price on carbon, is less common. The following sections describe the policy options in more detail.

5.3.2 Carbon Taxes

The taxation of GHG emissions is, in theory, the simplest carbon pricing instrument, especially if applied to the CO_2 emissions associated with fossil fuel combustion. By putting a price on CO_2 emissions, regulators can "internalize" the negative externalities associated with these emissions, i.e. the damages suffered by others. The resulting effect is an increase in the market price of fossil fuels, which in turn creates an incentive to deploy them more efficiently and substitute them with less carbon-intensive energy sources. According to economic theory, consumption of fossil fuels would then reach an optimal level.

The World Bank's latest "State and Trends of Carbon Pricing" report[66] lists 22 national and subnational carbon tax regimes around the world, with tax rates ranging from less than 1 USD/tCO_2 (Poland, Ukraine, and Mexico) to 139 USD/tCO_2 (Sweden) . Fundamental differences also exist in how proceeds from the tax are handled: in some cases they are used to supply public budgets or fund specific mitigation actions, whereas in others they are re-distributed to consumers. For example, the Swiss levy on heating fuels currently stands at 96 CHF/tCO_2 (100 USD/t) and about one third of the proceeds are used to subsidize the thermal rehabilitation of buildings, while the rest is redistributed to businesses and households.

[65] The World Bank, http://www.worldbank.org/en/programs/pricing-carbon, (accessed 30.7.2018)

[66] The World Bank Group, (2018), *State and Trends of Carbon Pricing 2018*, https://openknowledge.worldbank.org/handle/10986/29687, (accessed 30.7.2018)

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5.3.3 Cap & Trade Schemes

Next to carbon taxes, emissions trading systems (ETS) based on the cap and trade principle are the second fundamental option available to policy makers for internalizing the cost of GHG emissions and for reducing these emissions as efficiently as possible.

Under a cap and trade scheme, the regulator sets a yearly maximum for the aggregate emissions of a group of large emitters; the so-called "cap". Tradable emissions allowance are then allocated to these emitters, either for free or through auctions. Over time, the regulator can drive down the aggregate emissions in the scheme by tightening the cap. This results in an increased price per allowance if demand (i.e. emission levels) stays the same. The inherent effect will be a greater incentive for emitters to reduce their emission levels as it has now become costlier to keep emitting GHG emissions.

The regulated emitters are obliged to monitor their emissions and, typically once per year, surrender for cancellation a number of allowances equal to their emissions in the reporting period. In the climate policy context, each allowance corresponds to one metric ton of CO_2e. In the USA and in early literature, allowances are sometimes referred to as "permits", while in the EU, permits denote the operating permits of a regulated installation (Appendix B.2.4).

In most cap and trades schemes, allowances can be freely traded between regulated installations and third parties such as traders. Excess allowances can also be banked for use in future periods. The price of allowances creates an incentive to reduce emissions in those installations offering the lowest abatement costs. Aggregate emission reduction targets may thus be reached at the least-possible cost.

5.3.4 Carbon Offsetting (Baseline and Credit) Under Governmental Administration

"Baseline and credit" denotes project-based emissions trading mechanisms where individual emitters can earn tradable "carbon credits" over a defined period by reducing their emissions below a pre-determined baseline. Unlike in cap and trade systems, participation in baseline and credit schemes is purely voluntary for the emitters. Carbon credits are also referred to as "offsets" because the buyers use these credits to offset their own emissions.

From an economic perspective, carbon credits are a performance-based subsidy intended to make emissions-reducing activities financially viable. As with any subsidy mechanism, one of the biggest challenges is to ensure the "additionality" of the emission reduction projects, that is to keep the proportion of free riders to a minimum. Project owners see carbon credits as a reward for doing the right thing, while from the regulator's perspective, carbon credits are an incentive intended to trigger emissions-reducing activities which otherwise would not happen.

Carbon credits are issued by an independent regulator. Historically, the most important schemes were the Clean Development Mechanism (CDM) and Joint Implementation (JI), both anchored in the Kyoto Protocol and administered by the UNFCCC Secretariat.

Carbon offsetting mechanisms are often used in combination with carbon taxes where emitters can "offset" their carbon taxes with respectable carbon credits bought from emission reduction projects. Regulators are free to define the regulatory requirements of what type of carbon credits is eligible to be used in a specific offset scheme. Carbon offsets can also play a role in emission

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trading schemes where credits that are generated outside the scope of the ETS can be used as a substitute for the ETS allowances for surrendering purposes at the end of a reporting period. Again, the regulator can define the terms and conditions of this inclusion of external credits into the ETS.

5.3.5 Further Voluntary Carbon Offsetting Approaches

Voluntary approaches are defined here as carbon offsetting schemes where carbon credit standards are operated by non-governmental bodies as compared to the previous section focused on the CDM and JI mechanisms set up under the Kyoto Protocol.

The most important voluntary carbon credit standards (Figure 5-2 Breakdown of the voluntary market by standard. Source: Ecosystem Marketplace (2017)) are Verra (formerly the Verified Carbon Standard, VCS), the Gold Standard, the American Carbon Registry (ACR) and the Climate Action Registry (CAR). Such credits are mainly used to supply the voluntary corporate market, but are also accepted in some compliance schemes, for example in Colombia.

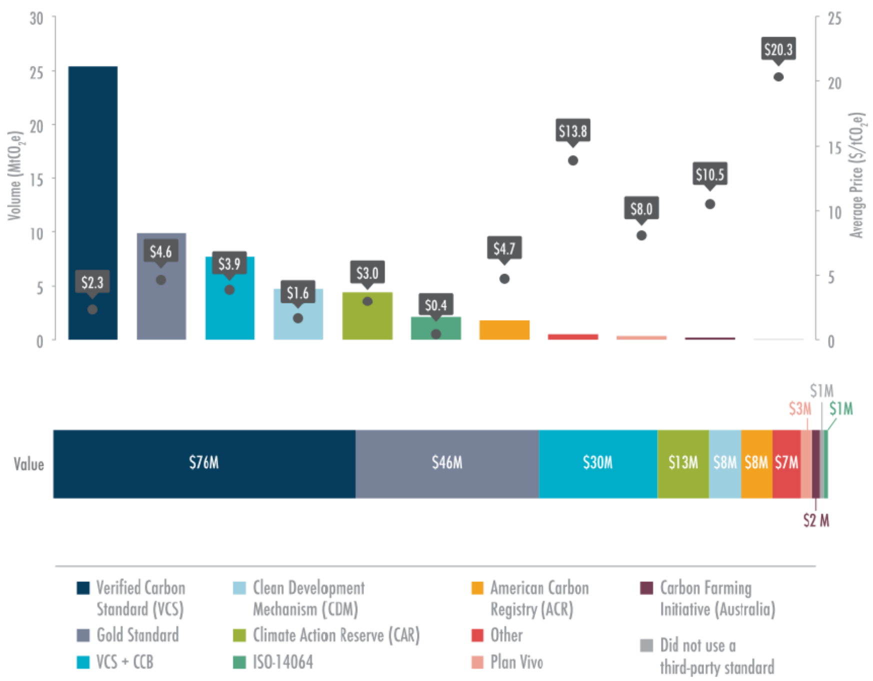

Figure 5-2 Breakdown of the voluntary market by standard. Source: Ecosystem Marketplace (2017)[67]

5.4 Carbon Finance Mechanisms

5.4.1 Emission Reduction Purchase Agreement

An Emission Reduction Purchase Agreement (ERPA) is a common contract that sets out the legal modalities for the transaction of carbon credits between two parties, be it under the Clean Development Mechanism established under the Kyoto Protocol, under an ETS or linked to a

[67] Ecosystem Marketplace, (2017), *Unlocking Potential: State of the Voluntary Carbon Markets 2017*, https://www.cbd.int/financial/2017docs/carbonmarket2017.pdf, (accessed 30.7.2018)

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voluntary standard. Some forms of transfers, such as those under the CDM or potentially under Article 6 of the Paris Agreement, need the official agreement of both the selling and buying Parties' Governments. The most common ERPA configuration is one where the seller of the carbon credits is the owner of the emission reduction project and the buyer – a compliance buyer or intermediary (trader, broker) – purchases the carbon credits at pre-defined terms (price, volume, tenor).

Pre-defined terms have benefits both to the project owner and the buyer. The project owner avoids the price risk and has more certainty in the investment decision. The main risk for the owner is that the project does not perform and that revenues will suffice to recover the investment. If the project does perform as planned, the ERPA ensures constant revenues despite potentially volatile market prices for carbon credits over the runtime of the tenor. For the buyer, an ERPA with pre-defined volumes and prices serves as a hedge for its future compliance or voluntary carbon costs.

Other potential price arrangements include "Index Linked" prices (i.e. a percentage of the carbon offset market price at time of delivery) or "Floor Price plus Participation" (i.e. fixed floor price per carbon offset on delivery plus a percentage difference between the floor price and the prevailing market price).

5.4.2 ERPA-backed finance

In mobilizing climate finance, ERPAs could have an additional positive effect besides reducing price and volume risk. A typical emission reduction project requires a substantial investment at the start of the project. A lead time to commission the project of more than a year is not uncommon. After generating the emission reductions, verification and issuance again take up time until the emission reductions can be commercialized at a market or pre-defined price with the ERPA-counterparty.

Pre-defined prices (or a floor price) in combination with a buyer that is assigned a high credit rating makes an ERPA a valuable security when it comes to debt financing. Project loans can be backed by the revenues from offset sales. Depending on the setup between the seller and buyer of the credits and the financing party, it could be arranged that offset sales revenues are in part directly transferred to the financing party, thus eliminating the counterparty risk of the credits seller. This will in turn lower the costs of financing for the project owner and render more potential emission reduction projects economically feasible.

The idea of ERPA-backed finance can be expanded as is done with similar financial products. A bundle of projects can be used under the same program to diversify the idiosyncratic project risk. Elements of structured finance and mezzanine financing can be introduced to appeal to different investor risk-types. However, the whole idea is based on a reliable, widely-accepted, accountable mechanism that enables strong and stable markets. Even with pre-defined prices, high volatile markets introduce pricing risks as the parties will want to get out of those contracts if current market prices are significantly above or below their agreed-upon price.

5.4.3 Carbon finance to de-risk H_2-CCS projects

Project developers along the H_2-CCS value chain could profit from entering an ERPA or accessing an ERBA-backed finance arrangement in order to secure an additional source of income from

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credit sales. This would strengthen the financial viability of the project and may increase the attractiveness of the investment for additional equity or debt investors.

However, carbon credit sales can only take place if the legal basis for the transfer of offsets from CCS projects to potential buyers is in place. In the voluntary carbon market, most standard and certification bodies responsible for verifying and issuing offsets have not endorsed CCS as an eligible emission reduction project type. The only organization with a published *Methodology for Greenhouse Gas Emission Reductions from Carbon Capture and Storage Projects* is the American Carbon Registry[68]. This may change as monitoring and verification equipment is being improved[69], and with more CCS projects coming into the pipeline - in particular in the US where a new tax credit law has brightened the prospect of CCS deployment within the country[70].

To what extent the compliance carbon markets will adopt CCS depends first and foremost on the upcoming rule book for the Paris Agreement. Whether or not the rule book will impose eligibility criteria for CCS activities under Article 6 remains to be seen. Concerning the cooperative approaches under Article 6.2, the Parties who negotiate an ITMO transfer should in principle be free to decide on the project type that is subject to ITMO transfers – given that the activity does not lead to emission reductions already covered by the NDC of the host country. Concerning the new market mechanism under Article 6.4 and depending on how closely the new rule book will follow existing CDM regulation, it is plausible that the eligibility of CCS under the CDM will be carried over.

[68] American Carbon Registry, https://americancarbonregistry.org/carbon-accounting/standards-methodologies/carbon-capture-and-storage-in-oil-and-gas-reservoirs (accessed 26.07.2018)
[69] https://markets.businessinsider.com/news/stocks/welldog-virginia-tech-and-carbon-geocycle-jointly-demonstrate-first-verification-of-carbon-dioxide-sequestered-in-underground-rock-formation-1027324430 (accessed 26.07.2018)
[70] https://www.iea.org/newsroom/news/2018/march/commentary-us-budget-bill-may-help-carbon-capture-get-back-on-track.html (accessed 26.07.2018)

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6 ADDRESSING BUSINESS RISKS

6.1 Overview

Table 6-1 below provides an example of how different types of de-risking measures can be applied to the principal business risks in a CCS chain for, and between, developers/operators, public authorities and financiers.

Table 6-1 Summary of typically identified CCS chain business risks and de-risking mechanisms

Liability/Business Risk	Contractual Treatment/Remedies/Insurance etc				
	Capture	Transport	Storage	Public Authority	Financier
Capture plant outage	• Emitter compensation from capture operator: loss of sales, carbon penalty, T&S service cost	• Emitter ship or pay • Annual/daily contract quantity	• Emitter use or pay • Annual/daily contract quantity	• N/A	• Minimum repayment thresholds • Insurance cover • New Technology/Supplier Guarantees and warranties • Counterparty creditworthiness • Emitter Sales Agreements
Transport outage	• Emitter use or pay • Annual/daily contract quantity	• Emitter compensation: loss of sales, carbon penalty, C&S costs	• Emitter use or pay • Annual/daily contract quantity	• N/A	• Minimum repayment thresholds • Insurance cover • New Technology/Supplier Guarantees and warranties • Counterparty creditworthiness
H_2 or CO_2 Storage outage	• Emitter use or pay • Annual/daily contract quantity	• Emitter ship or pay • Annual/daily contract quantity	• Emitter compensation: loss of sales, carbon penalty, C&T costs	• N/A	• Minimum repayment thresholds • Insurance cover • New Technology/Supplier Guarantees and warranties • Counterparty creditworthiness
Operational leakage – defined and limited events (including death)	• Solvent/pollution damage – compensation payments, insurability • Carbon penalty	• Consequential damages – compensation, insurability • Carbon penalty	• Consequential damages – compensation, insurability • Carbon penalty	• Statutory remedies • Public sector underwriting where no insurance available • Underwriting beyond limits on carbon pricing	• Insurance • Minimum repayment thresholds • Competency of contractors
Under-performance of CO_2 storage site	• N/A	• N/A	• Consequential damages • Remediation or Abandonment • Time limitations	• Underwriting of revenue compensation for C&T • Underwriting/Guarantee of Carbon penalty • Underwriting/Guarantee of debt repayment • Compensation for Storage Operator above agreed threshold	• Change of Control • Guarantees from Public Authority for minimum repayment thresholds • Regulatory Arrangements • Termination Provisions • Step in Rights • Decommissioning costs capping
Long term leakage from CO_2 storage	• N/A	• N/A	• Defined event liability limits • Defined volume and carbon price collar • Insurance for carbon allowance reimbursement (CARI)	• Risk sharing • Public sector underwriting where no insurance available • Underwriting beyond limits on carbon pricing	• Regulatory Arrangements • Capping of liability • Insurance cover
Change of policy or law related to CCS	• N/A	• N/A	• N/A	• Statutory mandates • Compensation payments • Umbrella or implementation agreements	• Regulatory Arrangements • Umbrella or implementation agreements
Indirect exposure to energy market	• N/A	• N/A	• N/A	• Guarantor of last resort • Compensation payments	• Guarantees from Public Authority for minimum repayment thresholds • Termination Provisions • Step in Rights

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The following sections explore in more detail mitigation of some of these principal business risks from the perspectives of the different stakeholders involved; namely owners/operators, financiers, and public authorities/governments. Note that some of these risks are related directly to investment barriers identified and discussed earlier in Chapters 4 and 5. For example the possibility of long term leakage from a storage site creates both an initial investment barrier (due to regulatory and financial requirements) as well as an ongoing operational business risk (due to penalty exposure and remediation costs). This narrative is followed by reviews of the standard contract-based de-risking mechanisms for construction financing and operating service agreements. Making use of contractual arrangements, or agreements, between parties allows for bespoke solutions to risk and liability sharing. However, all are built up from some standard mechanisms that become tailored to the specific project situation.

6.2 Owners and Operators: Equity

6.2.1 Role, Risks/Issues and Needs of Owners and Operators

Operators within the H_2-CCS chain will service multiple industries such as power generation, industrial CCUS, combined heat and power networks, hydrogen networks and transport fuel, leaving them exposed to the different dynamics of these markets for their revenues. Furthermore, financeable infrastructure projects and geological storage sites are required before emitters and other market and service customers can take FID on their own investments. Hence the infrastructure providers require investment de-risking (which is very substantial in the case of storage) ahead of market demand, because without any certainty of a market for their services any investment is purely speculative.

It is therefore difficult for infrastructure developers to make an investment case with uncertainty in demand requirements, while also being exposed to significant upfront financial and long-term liability risks (such as the case for CO_2 storage). They can only deliver returns to investors as part of a completed and operational H_2-CCS value chain, but their returns are highly dependent on the differing market drivers of the multiple end-use customers and various industrial and energy system policy mechanisms. The result is a limited or unknown income potential versus a risk exposure currently perceived to be too large and bearing no relationship to contract value received by the operator. Under these circumstances equity finance from sources other than developers is highly unlikely, and these structural issues create the investment barriers discussed in previous chapters. However, they also generate ongoing potential business risks related to such things as market development and growth, counterparty performance, technology and operational performance, and policy and political risk.

As discussed in Chapter 2, joint public and private sector partnerships (PPP) are a tried and tested way of dealing with the conundrum of infrastructure investment ahead of market demand, and H_2-CCS is no different. Hence private sector stakeholders ready to implement CCUS have consistently argued that from their perspective business risks can only be mitigated by sharing them with the public sector in a way that ensures value for money for the public purse while making commercial and financing structures feasible in the private sector. Public authorities will need to share in CCUS risks that cannot be allocated along the chain via contracts, and a special commitment from Government will be required to provide a backstop for uninsurable elements or CCS specific business risk items which are unable to be borne by the private sector.

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6.2.2 Options to Mitigate Risk and Ensure Commercial Benefit

An infrastructure developer that wants to implement a new project while protecting its corporate balance sheet against the risks associated with the project would typically establish a special purpose project company (SPV). Under a PPP structure that SPV could have contractual arrangements with a public authority to implement the project and raise the funding. The SPV is a company with no previous business and no projects aside from the infrastructure project on its balance sheet. As a result of high upfront costs and delayed revenue streams, infrastructure projects are normally structured via project finance. The ability of the private party to accept liabilities is therefore limited by its structure. The project company is legally independent from its shareholders. This provides a safeguard for the project in the event of failing shareholders dragging an otherwise healthy project into distress or vice versa.

The SPV will look to accept risks that it can transfer to third parties such as subcontractors (e.g. risks associated with design, construction and timely completion), customers and financiers. However, none of these parties is willing to accept extraordinary risks. Therefore, these risks remain within the SPV. Typically, these are risks related to the long-term nature of the asset and business: systematic risks (including inflation, revenue and interest rate), long-term performance risks (including uncertainty in timing and level of maintenance costs) and coordination risks (including interface issues between customers and subcontractors of the SPV, and potential underperformance or bankruptcy of these counterparties). Because of the ring-fenced operations of the SPV and its limited balance sheet, the only way to absorb these risks is by insuring against them or by financiers and investors accepting them.

Revenue and utilisation risks are handled contractually wherever possible by mechanisms such as take-or-pay, use-or-pay, compensation and penalties. Although these are standard arrangements in many business chains related to LNG and natural gas production and sales, the business risks associated with low market development and/or growth for hydrogen and CO_2 disposal will need further underwriting to ensure a satisfactory return on investment for the SPV.

Experience in the Netherlands, Norway and United Kingdom[71] shows that investors and project developers will require commitments from Government to underwrite extraordinary risks if private sector capital is to be attracted for CCUS infrastructure investment. These include market size, development and capacity utilisation, and the uninsurable elements or CCS specific business risk items that the private sector is unwilling to accept. In particular, insurers, financiers or operators will be unable to bear unlimited liabilities, so where liabilities are not limited in size, risk sharing with Government will be essential, for example to develop and operate CO_2 storage facilities.

There are a number of ways liabilities can be shared efficiently between public authorities and the private sector that can facilitate investment and lower the overall costs to Government. If the size of liabilities can be capped by Government, in combination with insurance risk transfer solutions, a viable risk management approach can be created that significantly reduces the cost of capital. An instructional example developer/operator business risk and mitigation assessment for CO_2 storage has been included in Appendix I.

[71] See for example: Dixon, P. and Mitchell, T., (2016), *Lessons and evidence derived from UK CCS programmes, 2008 – 2015*, http://www.ccsassociation.org/press-centre/reports-and-publications/, Carbon Capture and Storage Association, (accessed 30.7.2018)

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6.2.3 Defined Event Liability Limits

A common way of apportioning risk through contracts is for the parties to exclude or restrict their liability to one another in the event of default. The parties can seek to limit their liability under the contract in a number of ways, often by excluding liability for certain types of loss or by putting a financial cap on liability for such losses or imposing a short time limit for claims. This must also be balanced against any public authority concerns that a party who freely undertakes a binding contractual obligation should not be equally free to absolve itself from its duty to perform. Examples of defined event limits could include solvent or pollution damage from a capture plant, or damage from a pipeline rupture. Both of these can include environmental and property damages.

6.2.4 Defined Event Liability Limits for CO_2 Storage

Using limitation of liability clauses creates a mechanism to share risk between a public authority and a storage operator for "CO_2 Leakage Risk". CO_2 leakage is most likely to occur due to migration of the CO_2 within the subsurface or leakage at the surface. Loss of containment at the subsurface during operations is generally considered to be most likely the result of poorly abandoned wells. Defined event limits can be utilised to remove the potential unlimited leakage liability from the operator while ensuring they incentivise best practise to prevent leakages.

One example of a "Defined event Limit" would be to put a financial cap on liability for CO_2 leakage occurring at an abandoned well, fault or cap rock, dependant on the particular site risk profile, by assuming it leaks at a certain rate for a certain time. This can be risked and quantified.

Several early CCS-specific legal and regulatory regimes include provisions which may limit an operator's liability beyond the post-closure period. While these are perhaps not 'defined-event limits' in the truest sense, they may afford an operator a defined pathway for limiting their exposure to some liabilities attaching to their storage operations.

6.2.4.1 Defined volume and carbon price collar for CO_2 Storage

Unlimited CO_2 leakage liabilities will remain uninsurable because of their nature and insurance solutions do present commercial challenges for storage operators. However, solutions that offer limits on the liability can potentially be developed. One solution[72] would be agreeing a financial cap based on an agreed volume of stored CO_2 and a "ceiling and floor" (or "cap and collar") price. Alternatively, a moving average EUA price based on historical prices from a number of previous years could be used. This approach is analogous to how future electricity prices are dealt with in other insurance policies.

A price "cap and collar" is an example of a quantity-price hybrid that is intended to limit the storage operators and investors exposure to price swings by creating a price floor as well as a price ceiling. The price ceiling is achieved by providing additional allowances at a predetermined price. The price floor could, most likely, be implemented in one of two ways. If emissions allowances are auctioned, the regulator could set a minimum reserve price, which would serve as the floor.

[72] ClimateWise, (2012), op. cit.

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Alternatively, the regulator could promise to always buy and retire allowances at a predetermined floor price.

6.3 Financiers and Investment Funds: Debt

6.3.1 Role, Risks/Issues and Needs of Financiers

To entice investors any H_2-CCS business segment needs to be a competitively attractive investment with other opportunities. The uncertainty in revenue for CCS transport and storage businesses expose investors to too many risks and these are therefore not currently suitable for debt financing, particularly for investment funds.

Commercial banks, investment banks or other institutional investors provide the debt portion of project financing. Project financing is a specialised funding structure that relies on the future cash flow of a project as primary source of repayment, and holds the project's assets, rights and interests as collateral security. It is also referred to as non- or limited recourse finance, i.e. lenders have no- or limited recourse to the sponsors or shareholders of the project company for repayment of the loan. Lenders are, of course, very interested in the creditworthiness of counterparties to the various project contracts, and the efficacy of guarantees and warranties of suppliers.

Financiers are typically risk-averse, which means that they are not willing to accept much risk in a normal non-recourse project finance structure. In allocating risks between a public authority and private SPV, it is therefore important to understand how the SPV is organised - including its legal structure and its contractual arrangements with the subcontractors - and to what extent risks are accepted in the regular markets of subcontractors, insurers and financiers.

Hence, the predictability of the future cash flows and suitable risk profile are the most prominent requirements to enable project financing. This combination is required to facilitate higher gearing and attract debt finance, reduce the cost of capital and increase affordability for users, and to spread the capital costs over as much of the working life of the infrastructure as possible.

6.3.2 Options to Mitigate Risk and Prevent Commercial Loss

6.3.2.1 Regulatory Arrangements

For financiers and investors, certainty and transparency as to the nature of the legal environment in which a project will operate will be necessary to offset against upfront risks and the significant resources which will be needed to develop and deploy early projects. Technology providers, for example, view legal and regulatory frameworks as an important component of what they will require; "*to see a clear path to commercialisation in a market with reasonable sales potential*"[73]. Regulatory frameworks which legitimise broader domestic policy commitments and provide clear parameters for the operation of a project, throughout the project lifecycle, therefore offer increased confidence to both operators and investors.

[73] Shilling, N., '*Carbon Capture and Storage – An Equipment Manufacturer's Perspective*', in Havercroft, I., Macrory, M. and Stewart, R.B., 'Carbon Capture and Storage – Emerging Legal and Regulatory Issues', Hart, Oxford (2011), at page 32.

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Anything within the current investment (or missing market) regime for H_2-CCS infrastructure operators that impacts revenues will have significant implications for how potential financiers will evaluate the risks to financing such projects. When carrying out their financial assessment financiers will evaluate the worst-case scenarios that impact the project revenues in the event of changes in the market (development) or loss of key contracts to assess the asset value because this is the primary security for their loan. For example, geological storage assets would have no real value to financiers in a default scenario, so they will ultimately be relying on any certainty provided by a policy and associated implementation framework rather than the fundamentals of a storage project. It follows therefore, that for H_2-CCS projects to raise commercial bank financing there has to be confidence in long term policy and the enduring nature of the underlying support[74].

Financiers require regulations to also provide predictable and flexible permit criteria in order for them to calculate returns on the potential investment. They will want to mitigate the risk that a government will not change its regulation of the project's operation in such a way as to inhibit the project development and production plans, or the revenue stream.

To facilitate financing and make projects bankable, Government will need to underwrite the risk of policy and regulation changes to a sufficient extent through appropriate carve outs for large-scale H_2-CCS because, whilst industry may take risk on general changes to law/regulation, the retrospective changes to a number of European renewable incentive schemes has created significant sensitivity in the financial community to "Change-of-Law" risk. This mitigation can be provided through contingent support or guarantees by a public authority to a project SPV or other private sector participants.

The financiers will also need to review the reasonableness of restrictions for failure to operate to the standards required, the payment structure for financial penalties, and any further sanctions for project company breach many of which can be managed through contractual arrangements.

6.3.2.2 Insurance cover

Insurance is a vital risk mitigation mechanism for infrastructure projects. If there is a catastrophe affecting a project, then the project SPV and the lenders will look to the insurers to cover the losses because of their need for as much predictability as possible. Availability of insurance, levels of cover and deductibles will have an impact on the risks being taken by a public authority, the operator/ project SPV, and the lenders.

Often, the project SPV will simply obtain a comprehensive insurance policy for the entire project, avoiding any overlaps or gaps in insurance coverage. Nevertheless, when it comes to risks that are outside of regular packages, insurance may become difficult or very expensive to obtain. A large number of the operational risks in a H_2-CCS chain can be addressed through existing risk mitigation and risk transfer options that are familiar to the insurance, pipeline network systems, and oil and gas industries. However, a small number of the CCS specific liabilities remain uninsurable and will require alternative risk management solutions.

[74] Société Générale, (2014), *Financing Large Scale Integrated CCS Demonstration Projects,* GCCSI, https://hub.globalccsinstitute.com/sites/default/files/publications/157868/targeted-report-financing-large-scale-integrated-ccs-demonstration-projects.pdf, (accessed 30.7.2018)

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As insurance is a key area of interest for lenders and public authorities, they will want this to be organised in an arrangement with them. Lenders repayments are dependent on the stable cashflows of a project and they will seek to cover project losses by optimising the insurances available to protect these. Lenders are interested in ensuring that they are satisfied with the scope of the proposed insurance cover: the risks covered, the exclusions, the amount of cover and the deductibles, and that their interests in the insurances are adequately protected.

Some of the key requirements of financiers in project lending documents include:

- An undertaking to effect cover - borrowers will want to ensure that the obligation is to cover "to the extent that the insurances are available". This helps prevent the project company from being in default as a result of relevant insurance markets withdrawing certain insurance cover or raising premiums to unacceptably high levels;
- The mechanism for increasing insured amounts - e.g. index-linking or agreement between the parties, with resort to an expert in event of disagreement;
- An undertaking for approval of the insurance provider by the banks on terms acceptable to the banks;
- A requirement of the project company to inform lenders directly of any changes to the terms of the polices;
- A requirement of the insurer to give lenders notice of cancellation of a policy (so lenders may be able to pay the premium if cancellation is for non-payment, etc.);
- A requirement to advise the agent bank of any non-payment of premia and of any circumstances which might result in any insurance being avoided;
- An undertaking to pay all premia when due and to provide the agent bank with evidence of payment;
- A provision that if a borrower defaults in any of his insurance obligations, the banks can perform those obligations in his name and at his expense; and
- An obligation to apply substantial physical damage insurance proceeds in prepayment of loans.

6.3.2.3 Insurance for carbon allowance reimbursement (CARI)

There is no existing insurance risk transfer solution for CO_2 Leakage Risk. However, research by the ClimateWise Group[75] suggests that potential exists for new insurance products to be developed. ClimateWise proposed a "CARI" policy which, under tightly defined criteria, could provide cover for a subset of the total EUA liability operators would face. It would be purchased as an annually renewable insurance policy. This type of policy could also have application for defined events in the transport network and capture plant outages, in both cases where CO_2 is released to the atmosphere.

For storage operations, the CARI policy would apply to the injection phase in the first instance. Insurance for the post-closure phase appears more challenging due to the different nature of the risks involved. The risk exposure during the injection phase is gradually building up over the time that the CO_2 is being injected into the store and the storage operator is receiving a revenue stream based on the volume of the CO_2 being stored.

[75] ClimateWise, (2012), op. cit.

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During the post-closure period the volume of CO_2 stored is at its maximum and the risk exposure continues to grow as the price of EUAs escalates, while at the same time an operator is unlikely to be receiving income. The cost of an annually renewable insurance policy in the post-closure phase may therefore be less attractive compared to other possible risk transfer mechanisms.

In defining what the CARI policy could cover, it is helpful to draw on experience from existing analogous policies such as Control of Well (CoW) insurance, where all fluids escaping uncontrolled through a wellbore, including the caprock immediately over the wellbore, are covered. Causes for CO_2 leakage that may be included within the scope of a CARI policy concept are those that result in damage to physical assets owned by the insured from operational wells, abandoned wells and the caprock seal over the wellbores, all of which are classified as sudden or accidental events. These are also considered the more likely of the causes for a leakage event, although still with a very low likelihood of occurring. By modifying other environmental insurance policies, it might be possible to cover gradual seepage through faults and fractures.

As all insurance policies must indemnify the insured for a defined event, the CARI policy concept has to define parameters for the risk exposure, by agreeing an EUA price up front as the basis for which the policy would indemnify the insured following a leakage event. This means that the policy would operate on a “first loss” basis, because if the actual EUA price rose above the price agreed in the policy, the insured would retain that additional liability. A monetary deductible would also need to be agreed as there would be an expectation that the insured would retain a primary portion of the risk. Sharing in the financial consequences of an event incentivises the insured to take risk mitigation measures that reduce the potential damage and repair costs.

The lack of claims experience means the market price in the early years would probably be driven by a more conservative underwriting view of the risk which is normal in the development of a new insurance product.

Insurance solutions can only provide cover for a defined and limited liability. Under the current wording of the EU CCS Directive, this would still leave CCS operators with liability for any losses above the limit of the cover and creates challenges for whether the insurance premium could be attractively priced as it is payable upfront in accordance with the EU CCS Directive. As operators are unable to bear such an unlimited liability and high costs it undermines the case for an insurance solution playing a role without Government participating in the risk sharing.

6.3.2.4 Public sector underwriting for CO_2 Storage risks where no insurance is available

Liability capping is essential to financiers who are typically not willing to accept much risk in a non-recourse project finance structure because they have no security other than the project assets and service contracts. Project sponsors are also hesitant to accept liabilities on their balance sheets.

Storage risk, while considered to be a “low probability-high impact risk”, is still one area of which most financial institutions do not therefore want exposure to due to the lack of historical experience. They currently view storage as a potentially unquantifiable risk that cannot be priced from a financing perspective. Financiers, insurers and storage operators are unable to bear the potentially unlimited liabilities associated with storage development (arising from the EU CCS Directive) so risk sharing with government will be required to develop H_2-CCS at scale in Europe.

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In theory a public authority will be able to manage, through a careful approach to permitting and regulation of a storage project, their exposure to any risks acquired through transfer. Upon the point of transfer, in the post-closure phase, the public authority should have a high confidence that the risk profile is low. Post-closure transfer will already see an operator's liability limited, but the lack of precedent and full-scale projects creates uncertainty to investors for pricing the risk.

However, if the size of CO_2 Leakage Risk could be capped by Government in combination with an insurance risk transfer solution, a viable risk management approach could be created that significantly reduces the uncertainties faced by the CCS industry in relation to CO_2 Leakage Risk, and that will lead to lower costs and attract private sector capital investment.

The leakage liability regime will therefore need to be refined to distinguish between insurable and uninsurable risks and to provide a mechanism to cap liabilities for defined periods. This would also be enhanced by linkage to the available revenue support and public-private partnership model. Contractual mechanisms to cap liability through defined events can be used to limit carbon price risk and will enable new insurance products to develop because a storage operator's exposure can be determined.

The combined effect of these risk management mechanisms can help to balance the sharing of project risk between the public and private sectors while ensuring that the public authority's exposure to unnecessary large contingent liabilities[76] created through the capping of liability remains limited. Striking the right balance will help Government encourage infrastructure investment and the delivery of high-quality, cost-effective storage services, while at the same time aiding in the solution to the coordination conundrum of which investments within the H_2-CCS chain come first.

Over time it may be possible for public authorities or market-making institutions to develop a risk pooling approach to underwrite storage leakage liabilities. Such an approach offers benefits in terms of both diversifying risks and meeting regulatory requirements. Examples of energy risk mutual companies operating in the world include Oil Insurance Limited (OIL), the Offshore Pollution Liability Agreement (OPOL) and Nuclear Risk Insurers Limited (NRI).

A mutualised funding pool established amongst CO_2 storage operators could potentially cover all causes of leakage, unlike traditional insurance solutions. One issue with this approach is the need for significant initial capital injection in order to comply with the EU CCS Directive because of the requirement to have a Financial Security in place before being awarded a storage permit. In reality the role of Government in such a scheme is likely to be significant. The capital commitment to set up the fund is unlikely to be justified for any one country given that the probability of loss is very low and only a small number of facilities may be included in the scheme.

[76] Contingent liabilities require expenditure only if an unlikely future event occurs.

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6.4 Public Authorities

6.4.1 Role, Risks/Issues and Needs of Public Authorities

Governments do not have unlimited financial resources for delivering infrastructure and the PPP approach gives a public sector entity the ability to tackle its infrastructure investment in partnership with the private sector while limiting requirements from its own resources. As risk allocation within PPP delivery models is about risk sharing between parties, it allows certain project risks to be transferred to the private party, but some risks will still be retained by the public authority under a PPP contract.

The risks for which the public authority is responsible are often referred to as “compensation events.” Compensation events consist of special circumstances that are under the control of the public authority or are most efficiently managed by the public authority. Compensation events can also be those that present a risk that still represents value for money when assumed by the public authority, even if the circumstances are not under the control or manageable by the public sector.

Typically, a PPP contract specifies that as a result of the compensation event the private party must be left in a no-better or no-worse position than if the compensation event had not occurred. In other words, the private party will receive financial compensation for costs related to the occurrence of the event. Hence, public authorities can take on roles such as commercial underwriter and guarantor of last resort in order to remove business risks that cannot be borne by project developers.

Governments can make use of State agreements, or umbrella and implementation agreements, that do not fall strictly into the PPP category, but which bind multiple public and private sector parties together with risks, liabilities and remedies allocated formally between them. Such agreements are common with trans-national pipelines and LNG projects.

6.4.2 Options to Mitigate Risk and Reduce Financial Exposure

6.4.2.1 Risk management through regulation

Governments also have legislation, regulation and other statutory instruments at their disposal to implement risk sharing through a combination of mandates, consents and permits, both at the start and throughout the life of a project, along with contractual remedies, fiscal instruments and securities that can be imposed on developers/operators.

Many of the CCS-specific legal and regulatory models developed to-date offer de-facto examples of risk-sharing between operators and one or more public authorities. Regulatory frameworks apportion the risks associated with CCS activities throughout the infrastructure lifecycle, as well as offering clearly defined parameters to a public authority’s role and responsibilities.

Under the EU CO_2 storage model for example, the role and obligations of the public authority are set out in the CCS Directive, accompanying guidance documents and national Member State implementing legislation. While a public authority may ultimately bear the risk in some instances for the failure of an operator to act, there are clear parameters to their obligations and opportunities throughout a storage project lifecycle for the authority to influence the behaviour of an operator, in order to minimise their risk exposure.

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The EU Directive's management of storage liability, throughout a project lifecycle, provides a tangible example of how risks may be shared between an operator and a public authority. Under this approach the operator will bear all the risks and liabilities associated with operating a storage site, up until the point of their transfer to a Member State's competent authority post-closure. By obliging operators to have upfront "Financial Security" in place before commencing injection, which is later replaced by a financial mechanism prior to transfer of the liability for the storage site back to the public authorities, the relevant national authority (Competent Authority) can protect itself against the event it is required to step in under the terms of the Directive.

6.4.2.2 Commercial/financial options

Public authorities are able to assess the technical competence and experience of project developers in executing projects of a comparative nature, handling technologies and equipment of a similar size. The project structure and track record of the engineering, procurement, and construction contractor or equipment suppliers will all contribute to minimising the likelihood of an adverse risk materialising and increase a project's likelihood of success.

The management's capacity to run the business also plays an important role in assessing the management quality and ability to deliver. The qualification and past experience of the management team, integrity and reputation in the financial community, compliance with regulatory and legal requirements, and track record of honouring contracts and operational and financial commitments would all be considered.

Despite the non-recourse nature of debt financing in many infrastructure projects, the financial strength of the parent company or sponsors is an important consideration as the parent company or sponsors invest the equity portion in the project and any financial trouble faced by the parent company or sponsor can jeopardise the implementation of an infrastructure project.

A public sector authority is able to minimise and manage these risk exposures through carrying out appropriate due diligence and financial appraisal of developers. In the context of EC rules, financial appraisal is a selection criterion and is designed to identify the financial risks to be assessed alongside other relevant qualitative and quantitative factors that can be grounds for selecting a candidate to tender or negotiate when bidding for significant public sector contracts[77].

The credit rating is one measure to assess the financial strength of the parent company or project sponsors. The credit ratings of the major rating agencies such as Moody's or Standard & Poor's reflect each agency's opinion of the financial strength and ability of the issuer to repay obligations punctually. Their rating reports take account of a company's corporate strategy, operating position, financial management and general prospects, and should be noted by the Authority. Lower ratings generally result in higher borrowing costs.

[77] See for example: European Commission, (2015), *Public Procurement Guidance for Practitioners*, http://ec.europa.eu/regional_policy/sources/docgener/informat/2014/guidance_public_proc_en.pdf, (accessed 30.7.2018)

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6.5 Mitigation Measures for Project Finance: Construction Phase

6.5.1 Conditions Precedent

It will be apparent from the previous discussion that financiers are very interested in the risks of both constructing an infrastructure project and operating it. Conditions precedent in a financing contract define all those things that must be in place before the financiers are prepared to release funds to a developer. Depending on the complexity of a project, these conditions can be very substantial and usually involve the actions or complementary investments of third parties. Likewise, contracts between entities constructing, operating or using infrastructure will include conditions precedent relevant to their individual commercial relationship.

Examples of conditions precedent include the following:

- Statutory and regulatory approvals/permits;
- Any linkages between parties in an umbrella, implementation, or State agreement - For H_2-CCS this would ensure the entire chain investment and initial customer market occurs;
- Window for start of services, deliveries, delays - this handles the coordination required to bring multiple facilities in the H_2-CCS chain online before functioning in full service operational mode;
- Commissioning/turn-down - addresses the other aspect of coordination, being the need for testing, fixing start-up problems and operating at less than contractual capacity;
- Allocation of different types of technical and commercial risk between parties; and
- Other project structuring and financing requirements.

6.5.2 Commercial Instruments

A variety of penalties, remedies and security instruments are used in the numerous contracts related to the construction period of a project. Many of them can be linked in the event that one or more performance obligations or conditions precedent are not met (Table 6-2).

Table 6-2 Example risks and contractual treatment during construction (after Ruster[78])

Contract Mechanism	Cost overruns	Delays	Start-up and testing problems	Contractor payment defaults	Hidden defects	Force majeure
Liquidated damages	X	X	X			
Performance bonds				X		
Retainage accounts				X		
Warranties					X	
Contingency funds	X	X	X	X		X
Insurance		X				X

[78] Ruster, J., (1996), *Mitigating Commercial Risks in Project Finance, Public Policy for the Private Sector, Note 69*, The World Bank

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An SPV, project owner, or sponsor can contract in various ways for the construction and delivery of facilities. The financier of the project sponsor will need the risks allocated between the various participants to be covered sufficiently to de-risk its loan. A Lender's security package will contain a number of de-risking instruments to cover its exposure to these various risks. The following is a summary of the principal instruments that can be used, as described in Ruster[79].

6.5.2.1 Liquidated damages:

Any contractor involved in the delivery of a project will be required to make compensation payments if they have not performed their contractual obligations. These can include delays, cost overruns, start-up and technical problems. Liquidated damages are often capped at a percentage of the contract price, such as 10-15% for pipelines or 30% for oil and gas facilities[80].

Some examples of liquidated damages payments are:

- Equity investors interest costs, lost income, fixed costs; and
- Buydowns to pay down project debt so debt service coverage ratios (DSCR) are kept constant if there is a reduction in operating cashflow.

6.5.2.2 Performance bond

Liquidated damages obligations themselves need to be covered in the event a contractor is unable to pay. Hence financiers require performance bonds or other forms of surety from low risk third parties such as banks to underwrite the payment obligations. It is typical to accrue a monthly amount, for example 5-10% of project sponsor payments to a contractor, in an escrow or retainage account to help provide a buffer to collection of liquidated damages payments.

6.5.2.3 Warranties

As with the purchase of any product, a "manufacturer's warranty" is required to cover hidden defects arising from faulty workmanship, materials, equipment or design after hand-over of the project facilities. Warranties come in various forms including evergreen or time-limited.

6.5.2.4 Contingency funds

Project sponsors and contractors can agree how to handle contingency in construction budgets. The risk of cost overruns or other "contingency events" (such as environmental remediation) can be carried by one or the other, or both parties. Likewise, financing of contingencies may be divided between debt and equity providers in various ways. Other sources of contingency funds can be provided by third party contractors (such as contingent sub-ordinate debt), SPV parent company guarantees, or standby letters of credit. Generally, such additional sources of funds will be capped in amount and limited in scope and when they are available.

[79] Ruster, J., (1996), op.cit.
[80] PriceWaterhouseCoopers, (2016), *EPC Contracts in the oil and gas sector*, https://www.pwc.com.au/legal/assets/investing-in-infrastructure/iif-5-epc-contracts-oil-gas-feb16-3.pdf, (accessed 30.7.2018)

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6.5.2.5 Insurance

Insurance is a reliable way of mitigating many risks in business-as-usual situations. It is often possible to make use of standard policies; however, insurers are adept at creating bespoke solutions for situations where risks are readily quantifiable. Examples of cover types include:

- Construction All Risk;
- Advance Loss of Profits; and
- Miscellaneous Cover.

6.6 Mitigation Measures for Project Finance: Operational Phase

6.6.1 Overview

Previous sections and chapters have shown the myriad risks that an infrastructure operator can be exposed to, and which can strongly influence the ability to re-pay debt as well as to make returns above an investment hurdle rate. This section is a summary of the key contractual instruments used between service contract counterparties described by Rusler[81], and which will inform a financiers' view of the viability of debt servicing (Table 6-3).

Table 6-3 Example risks and contractual treatment during operations (after Ruster[82])

Contract Mechanism	Operating efficiency problems	Increase in routine O&M	Increase in major O&M	Market demand and pricing	Input availability	Force majeure
Take-or-pay				X		
Put-or-pay					X	
Pass-through		X		X		X
Debt service reserve funds	X		X		X	X
Maintenance reserves			X			
Cash traps	X	X		X		
Insurance						X
Tracking accounts				X		
Equity kickers				X		

6.6.2 Commercial Instruments for Operating/Service Contracts

A more detailed treatment of commercial structures will be undertaken in ELEGANCY report D3.3.3 as a key part of the H_2-CCS business model selection process. The current summary completes the review of key instruments that can be used to share and mitigate operational risks. In the case of the H_2-CCS chain, innovation away from the standard is required, just as was the case in the early days of the international LNG industry.

[81] Ruster, J., (1996), op.cit.
[82] Ruster, J., (1996), op.cit.

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6.6.2.1 *Use-or-pay; Supply-or-pay*

One of the most important mechanisms for an infrastructure service provider to de-risk their project during the operational phase is the ability to lock-in a fixed portion of their projected income stream to shield revenues from market and price uncertainty. This provides financiers with a form of guarantee that re-payments can be covered, and it provides the project sponsor with greater certainty that it will meet its required investment return. The take-or-pay, or ship-or-pay, arrangement obliges the customer to pay for the service even if they have not used all of their "booked" entitlement. The service provider will have an obligation to provide a minimum availability or capacity, and to have administrative processes to enable bookings, account for usage and balance shortfalls or makeups.

Put-or-pay contracts are a variation that ensures a secure supply to a facility of some input feedstock. In this case if the supplier does not deliver sufficient input it will indemnify the project company for a variety of losses such as third-party compensation, revenue losses and inability to perform with its own customers. This contract mechanism structure could be used in a tolling facility, such as hydrogen production in a SMR utilised by natural gas producers.

6.6.2.2 *Pass-through*

From a commercial perspective, operators are often sandwiched between input costs and supply risks, and output income and service risks. Pass-through is a way of having back-to-back arrangements that help to mitigate the operator's exposure to this "squeeze". Examples include

- Back-to-back price indexation/escalation, caps, floors, collars;
- Force Majeure mirroring, and
- O&M cost escalation.

However, pass-through cannot help with technical underperformance (e.g. lower than expected efficiency).

6.6.2.3 *Contingency Reserves*

Contingency reserves are used to cover shortfalls in expected cashflows. The reserves allow for debt repayments and extraordinary expenses such as catastrophic events (force majeure) and a hedge against higher O&M costs in the future. Contributions to the reserves can come from various sources such as parent company equity contributions, standby letters of credit, and excess cash flows.

6.6.2.4 *Cash Traps*

Cash traps are another form of retainage or escrowed account that enable a project to meet debt repayments even if cashflows are not sufficient to meet the debt service coverage ratios required in the loan conditions. Net income is channelled into the account and applied to debt payments ahead of any disbursement to project sponsors. This "claw-back" by financiers will have conditions attached so that non-compliance would ultimately lead to default and all excess cashflow would service the debt as a priority.

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6.6.2.5 *Insurance*

During the operating period of a project insurance cover will be taken out for events such as:

- Property damage, business interruption, loss of revenue;
- Third party general liability; and
- Health, Safety and Environmental incidents.

The risks for H_2-CCS chains, and geological storage in particular, described in previous sections and chapters will require further innovation of insurance products and mutualisation to cover the unique characteristics of the risk profile and potential events.

6.6.2.6 *Risk compensation*

Risk compensation is a means for investors and other parties with a contractual relationship to a project to share in the project’s upside potential by accepting pre-agreed risks. This reward for risk sharing can be applied to input contracts or customer service contracts to help mitigate market and commodity price risk for the project sponsors, and also directly to investors. Example mechanisms include:

- Price tracking accounts, collars, and thresholds; and
- Equity kickers such as convertible debentures, preference shares, equity warrants, and contingent interest payments; all of which bestow a priority on the holder over the ordinary shareholders and investors.

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7 THE PROJECT/INFRASTRUCTURE RISK PROFILE

7.1 Putting it all together

The WP3 methodology leads to "maps" that can provide useful summaries of the key hurdles to investment and risks to business operations. These maps are then used for dialogue between stakeholders to determine preferences for risk sharing and the types of instruments available to be used between them. If possible, combinations of public and private solutions can be structured and re-structured over the lifecycle of infrastructure or an individual project for transitioning between public intervention to solely private sector commercial mechanisms as a market materialises and matures.

Figure 7-1 demonstrates the high-level risk profile and mitigation preferences for a full lifecycle H_2-CCS infrastructure case study. Such maps demonstrate where gaps in risk mitigation instruments exist (usually creating investment barriers for the private sector) and can be used at increasing levels of detail in different business segments. They will be used in the next steps of the methodology to guide business model selection and recommendations for policy support. Taking a top-down holistic approach to business models is a more efficient way with a higher likelihood of success for solving investability issues related to H_2-CCS infrastructure then has been the typical approach in Europe to date[83].

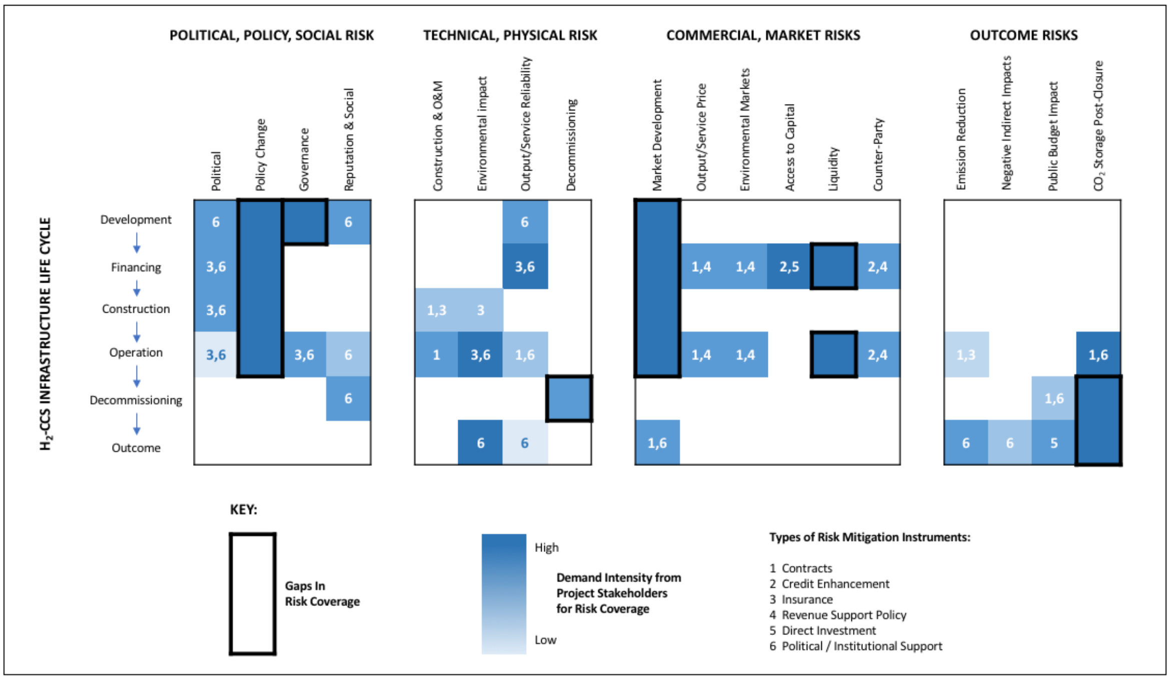

Figure 7-1 Example H_2-CCS chain demand for risk mitigation instruments (modified from CPI[84])

[83] See for example: UK CCUS Cost Challenge Taskforce, (2018), op. cit.
[84] CPI, (2013), op. cit.

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7.2 Additional Reading

The following additional references provide useful introduction to, and coverage of, various concepts presented in this report:

Durusut, E. and Pusceddu, E., (2017), *Deployment of an industrial Carbon Capture and Storage cluster in Europe: A funding pathway*, i24C, http://i2-4c.eu/financing-industrial-ccs/, (accessed 30.7.2018)

Goldthorpe, W., Ahmad, S., Eldering, L., Sannes, O., Baker, A., Grosvenor, D., .Dean, T. (2016). *A need unsatisfied - Blueprint for enabling investment in CO_2 storage.* London, UK: Deloitte/The Crown Estate.

HM Treasury and UK Trade and Investment, (2014), *Investing in UK Infrastructure*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/357135/infrastructure_pitchbook_28072014.pdf, (accessed 30.7.2018)

Hughes, C., (2013), *Capacity Charging Mechanism for Shared CO_2 Transportation and Storage Infrastructure*, National Grid Carbon Limited, the Global CCS Institute, https://www.globalccsinstitute.com/publications/capacity-charging-mechanism-shared-co2-transportation-and-storage-infrastructure, (accessed 30.7.2018)

International Monetary Fund, (2006), *Public-Private Partnerships, Government Guarantees, and Fiscal Risk*, https://www.imf.org/External/Pubs/NFT/2006/ppp/eng/ppp.pdf, (accessed (30.7.2018)

Zero Emissions Platform, (2014), *Business models for commercial CO_2 transport and storage*, http://www.zeroemissionsplatform.eu/library/publication/252-zepbusmodtransportstorage.html, (accessed 30.7.2018)

A EVALUATION TOOL SUITE

The following spreadsheet tools available for conducting the assessments of policy issues, business risks and de-risking instruments are included as separate files attached to this document.

A.1 Policy and Financial Support

Policy Gap Analysis Tool v2.1.xlsx

A.1.1 Exemplar Policy Assessments

Policy Gap Analysis Tool Germany Exemplar.xlsx

Policy Gap Analysis Tool Switzerland Exemplar.xlsx

A.2 Risk Assessment

Risk Assessment Tool v3.3.xlsx

A.2.1 Exemplar Risk Assessments

Risk Assessment Tool CO2 T&S Exemplar v1.2.xlsx

Risk Assessment Tool Hydrogen Production Exemplar v1.2.xlsx

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B EUROPEAN UNION

B.1 Innovation Policies

The EU has an overarching research and innovation technology plan. This is described below along with the main organisations and EU funding instruments for Research & Innovation (R&I) in Hydrogen and Fuel Cell (HFC) and CCUS:

1. The Strategic Energy Technology Plan (SET-Plan)
   The European Commission's integrated SET-Plan coordinates and prioritises better R&I activities across Europe by bringing together researchers, countries and industries and pooling their skills, talent and facilities. The 2017 SET-plan highlights CCUS as an important technology for the decarbonisation of power generation and energy intensive industries. Hydrogen is also referenced for the decarbonisation of transport, use in industry, energy efficiency and integration with CCUS. The implementation plans[85], which were endorsed in September 2017 list 8 R&I priorities for CCUS and present hydrogen in a demonstration project for steel manufacturing. A Working Group, bringing together the EC, governments, industry and the research community is responsible for coordinating and monitoring progress of the SET Plan Implementation Plan for CCS and CCU.

   Ten European Technology and Innovation Platforms (ETIPs) have been established in selected technologies that bring together stakeholders from the public and private sectors as well as researchers and NGOs. The secretariats of these ETIPs are co-funded by the Commission. Their purpose is to provide advice to the Commission, disseminate information and help promote uptake of energy technologies including through accelerating R&D and innovation activities. The CCS Platform is known as the Zero Emissions Platform (ZEP) and is a member of the Set Plan Working Group described above. There is no hydrogen platform, however the ZEP and other platforms do address hydrogen-related technologies.

2. Horizon 2020 and European Structural and Investment Funds (ESIF)
   The EU Commission promotes innovation activities and the commercialisation of technologies through the Horizon 2020 programme and the ESIF. The Horizon 2020 budget is €80 billion to carry out research on new ideas and facilitate their market adoption and deployment whilst the ESIF budget is €110 billion to finance and support innovation through entrepreneurship, SMEs and regional specialisation.

   Horizon 2020 is EU's framework research and innovation funding programme to deliver the Innovation Union, the EU strategy to foster innovation in order to secure Europe's competitiveness globally. Its funding is for the 7-year period from 2014 to 2020 to facilitate the transition of new ideas from research to the market. The programme provides significant funding to many projects in the area of Energy and Transport across multiple platforms, and has already funded a number of technical projects related to carbon capture and storage, and many forms of renewable energies. A new framework programme ("FP9") will be implemented when H2020 finishes in 2020.

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[85] https://setis.ec.europa.eu/system/files/set_plan_ccus_implementation_plan.pdf (accessed 30.7.2018)

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3. The Joint Research Centre (JRC)
JRC is part of the European Commission and provides independent technological and scientific advice to support EU policy decisions. It is funded by the Horizon 2020 programme for its non-nuclear work. Total budget is circa €330 million per annum. The JRC carries out scientific and knowledge dissemination on CCUS and is researching the safety and storage aspects of hydrogen and fuel cells.

4. Fuel Cells and Hydrogen Joint Undertaking (FCHJU)
The FCHJU is a unique public private partnership formed in 2008 by a European Council Regulation with three members: the European Commission, fuel cell and hydrogen industries (represented by Hydrogen Europe) and the European research community (represented by Hydrogen Research Europe). The objective is to facilitate the market introduction and deployment of these technologies and develop a sustainable and competitive Hydrogen and Fuel Cells sector – which will contribute to the objectives of the Strategic Energy Technology plan (SET-plan) adopted by the European Council. The FCHJU has a budget of €1.33 billion for the period 2014-2020 from all its members. The EU Commission's share of the funding (€665 million) comes from the Horizon 2020 Framework.

   The FCHJU funds a broad set of R&I activities including a number of studies and reports but also collaborative projects such as Hydrogen Mobility Europe, where 40 partners (municipalities, research centres and universities, industrial partners) from 9 countries aim to expand the fleet of hydrogen fuelled vehicles across Europe and create a trans-European network of refuelling stations.

5. European Research Area (ERA-NET)
ERA-NET is a co-funding "top-up" and support instrument under Horizon 2020 to aid in the formation of pan-European research and innovation projects and joint calls in selected fields of interest and relevance for Europe. The current ELEGANCY project is an example use of funds for the Accelerating CCS Technologies (ACT) joint programme established by a number of member states.

   From a European Commission perspective, the objective is to increase the share of direct funding from member states through public-public partnerships that pursue a joint purpose. Through the leverage the Commission funding brings there is an incentive to enhance networking and knowledge dissemination as well as bring greater alignment between research organisations in different countries.

6. Joint Technology Initiative (JTI)
JTIs were set up under the previous EU's Research and Innovation Programme, the 7th Research Framework Programme (FP7 2007-2013) by the European Commission as a new model of public-private partnership to support trans-European research with greater scale and impact. Five JTIs were set up in areas that have high industrial and policy significance for the EU.
Hydrogen and Fuel Cells was one of the JTIs and it provided funding for a number of projects. Some of these projects are still running, for example the Hydrogen For Innovative Vehicles (HyFIVE) project where the 5 main global manufacturers of FCEVs (BMW, Daimler, Honda, Hyundai and Toyota) and 10 refuelling infrastructure providers are

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deploying FCEVs and refuelling stations to validate performance on the road and connect clusters of stations.

7. EU ETS Innovation Fund
   As part of the revision of the EU ETS post 2020 and as a follow up of the NER300 programme (which had planned to invest €2.1 billion in a number of renewable energy projects including one CCS project – the UK's White Rose project), the EU Parliament and Council of Ministers agreed on 22 November 2017 to set up:
   a. an Innovation Fund worth circa €3.5 billion (450 million EU ETS allowances at current prices) for the period 2021-2030 in order to support innovative demonstration projects in energy intensive industries, renewable energy and CCS; and
   b. a Modernisation Fund which will be financed by auctioning 2% of the total allowances to encourage energy efficiency and the modernisation of the energy sector in member states with a GDP per capita below 60% of the EU average

8. European Energy Research Alliance (EERA)
   EERA is an alliance of more than 170 European public research centres and universities across 27 European countries and is the main research instrument to deliver the priorities for low carbon technologies of the SET-plan. EERA aims to optimise the national energy research facilities and align national and European R&D programmes by pooling the best talent and resources beyond national borders. The secretariat is funded by the European Commission with a seven year budget of €5 million through to end 2020. EERA is actively working on 17 Joint Research Programmes where participating countries collaborate with each other and with industrial partners and build on their own national research to accelerate the development and market introduction of world-class technology and foster innovation for Europe's energy sector.

   EERA includes a Joint Programme on CCS (launched in Nov 2010) focused on technical research work in capture, transport and storage and a Joint Programme for Hydrogen and Fuel Cells focused on technical research work on catalysts, electrolytes, materials, production, and storage. The CCS Joint Programme is a member of the Set Plan Working Group described above.

9. The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)
   The EU is a member of IPHE, an inter-governmental partnership to promote and facilitate the transition to low carbon economies by the use of fuel cells and hydrogen technologies. It fosters collaboration and information sharing between countries and is focused on international R&D, development of codes and standards, technical and commercial demonstration of hydrogen and fuel cell systems, and the infrastructure development and regulatory and policy actions to facilitate their early adoption and market deployment.

10. Mission Innovation
    The European Commission, along with many European Member States, has also joined the international initiative Mission Innovation with 20 of the World's major economies on behalf of the EU to accelerate global public and private clean energy innovation, and is expected to allocate €10 billion of funding through Horizon2020 for the period 2014-2020.

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B.2 Policies for H_2 and CCUS Delivery

B.2.1 Current Policy Development

At the time of writing the European Commission had opened a consultation for the development of a long-term strategy for Europe to meet its obligations on emissions reductions under the Paris Agreement, taking into account member state national plans. The European Council and European Parliament have both requested the Commission to present a proposal for this strategy through to mid-century. The strategy must not only address cost efficient pathways for decarbonisation, but also socio-economic factors and benefits such as modernising the economy, improving citizens quality of life, tackling social challenges and creating a circular re-industrialised low carbon economy.

In parallel with this consultation the Commission also published a proposal for a regulation on the establishment of a framework to facilitate sustainable investment. Climate change mitigation is one of six objectives with a number of priority activities relevant to CCUS and hydrogen delivery including:

- increasing carbon capture, utilisation and storage;
- phasing out anthropogenic emissions of greenhouse gases, including from fossil fuels;
- establishing energy infrastructure required for enabling decarbonisation of energy systems;
- producing clean and efficient fuels from renewable or carbon-neutral sources.

These policies will frame the future investment possibilities for hydrogen and CCUS beyond 2020.

B.2.2 Connecting Europe Facility

In 2013 the EU introduced the Connecting Europe Facility (CEF), a financial support mechanism for pan-European infrastructure investment in the areas of transport, energy and telecom at a network level with the purpose of improving the connectivity between member states and enhancing Europe's global competitiveness. Total funding budget is €30.4 billion (€22.4 billion for Transport, €4.7 billion for Energy, and €0.3 billion for Telecom). In the Energy section, the CEF funds a number of Projects of Common Interest (PCI), major cross-border projects that connect the energy systems of EU countries. In June 2018 the Commission released €500 million for a third round of PCI funding with the call closing in October 2018 and funding to be awarded in early 2019. Four projects related to CCS have been adopted for inclusion in the eligible list to apply for CEF funding: CO_2 Sapling Transport Infrastructure Project; Teesside CO_2 Hub (UK); Rotterdam Nucleus (NL); and a CO_2 cross border transport project connecting CO_2 emission sources in Teesside (UK) and Eemshaven area (NL) to a storage site on the Norwegian Continental Shelf (NCS).

Regulation (EU) no. 347/2013 of 17 April 2013 provides the governing guidelines for trans-European energy infrastructure. The CEF does not specifically include infrastructure associated with hydrogen. However one of the evaluation criteria for assessing gas PCIs in the regulation states: "Sustainability shall be measured as the contribution of a project to reduce emissions, to support the back-up of renewable electricity generation or power-to-gas and biogas transportation, taking into account expected changes in climatic conditions." This provides a PCI interface/interaction with potential hydrogen production and distribution infrastructure.

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B.2.3 Energy Policy

In November 2016, the EU Commission adopted the "Clean Energy for All Europeans" package, a package of legislative measures in support of the European energy and climate objectives for 2030 and aimed at leading the clean energy transition whilst retaining its economic competitiveness and delivering on jobs and growth and a fair deal for consumers. The measures covered energy efficiency, renewable energy (27% renewable energy target for 2030), the design of the electricity market, security of electricity supply and governance rules for the Energy Union.

On 28th November 2017, the European Parliament's industry and energy committee voted for a EU binding target of 35% renewable energy and 40% energy efficiency target for 2030 and it is expected that the new energy efficiency and renewable energy directives will become law in 2018.

It is recognised in the EU's Energy Policy that innovation and new technology development is essential not only to meet the climate change objectives, but also create new employment and growth. Research and Innovation will contribute significantly to maintain Europe' position as a leading player in the area of low carbon technologies. This policy gets implemented via the SET-Plan described above.

At the same time as the adoption of the Clean Energy for All Europeans" package, the EU Commission adopted the communication "Accelerating Clean Energy Innovation" and put forward measures to encourage private investment in clean energy innovation which are focused on three key themes: targeted signals, policies and standards and regulations to create the right business environment, targeted financial instruments to lower the investment risk and targeted R&I funding mainly through Horizon2020.

With regard to transport, the European Alternative Fuels Infrastructure Directive was adopted on 29 September 2014 and its implementation is underway. It requires member states to develop national policy frameworks to allow the market development of such fuels (which include hydrogen) and their associated infrastructure within two years, defines timeline for the deployment of such infrastructure (by 2025 for hydrogen) and specifies the need to define common standards and specification for the refuelling stations.

Transport accounted for 26% of CO_2 emissions in the EU in 2015. In June 2016, the EU Commission presented its European Strategy for Low-Emission Mobility. Its main elements are: increasing efficiency of the transport system, accelerating the deployment of low emission alternative energy for transport (such as advanced biofuels, electricity, hydrogen and renewable synthetic fuels) and a strategy for moving towards zero-emission vehicles (including revised emission standards and new legislative framework).

In November 2017, the EU Commission presented the Clean Mobility Package to turn this strategy into reality and includes new CO_2 standards (30% lower in 2030 compared to 2021), a Clean Vehicles Directive, an action plan and investment solutions for the deployment of alternative fuels infrastructure across Europe, a revision of the Combined Transport Directive and a battery initiative.

Buildings and their energy consumption represented 36% of CO_2 emissions in the EU in 2015. In February 2016, the EU Commission proposed a Strategy for Heating and Cooling which

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highlighted the potential efficiency improvements available from the use of micro-CHP using hydrogen.

B.2.4 European Emissions Trading Scheme

On 22nd November 2017, the Council of Ministers voted to revise and strengthen the EU Emissions Trading System (ETS) post 2020 and a new EU ETS Directive came into force in February 2018. The reformed ETS includes[86]:

1. A reduction in the overall emissions cap by 2.2% annually (linear);
2. The number of allowances to be placed in the market stability reserve will be doubled temporarily until the end of 2023;
3. A new mechanism to limit the validity of allowances in the market stability reserve above a certain level will become operational in 2023;
4. Additional mechanisms to protect industry from carbon leakage and cross-sectoral corrections such as:
    - Revised free allocation rules - the sectors at highest risk of relocating their production outside the EU will receive full free allocation. The free allocation rate for sectors less exposed to carbon leakage will amount to 30%;
    - A gradual phase-out of free allocation for the less exposed sectors will start after 2026, with the exception of the district heating sector;
    - Funding mechanisms to support industry meet the challenges of investment to transition to the low carbon economy (Innovation Fund and Modernisation Fund – see above);
    - The new entrants' reserve will initially contain unused allowances from the current 2013-2020 period and 200 million allowances from the market stability reserve. Up to 200 million allowances will be returned to the market stability reserve if not used during the period 2021-2030;
    - Member states are allowed to continue providing compensation for indirect carbon costs in line with state aid rules.

C NETHERLANDS

C.1 Innovation Policies

The Dutch government has funded, and continues to fund, numerous H_2 and CCUS research projects through institutes such as TNO, ECN, and national universities. ECN became part of TNO in April 2018 and will be the Netherland's centre of excellence for energy issues and research. The Dutch national programme for CCUS, now in its third phase, is known as CATO and has been in operation since 2004. There are almost 40 partners in the programme including the above research institutes, universities and companies like Shell, EBN, Gasunie, Taqa, Nuon and Tata Steel. The current phase of CATO is jointly funded from a variety of public sector sources, EU H2020 initiatives like ERA-NET, and bilateral arrangements (such as with Norway's

[86] Council of the EU, http://www.consilium.europa.eu/en/press/press-releases/2018/02/27/eu-emissions-trading-system-reform-council-approves-new-rules-for-the-period-2021-to-2030/pdf Council of the EU, http://www.consilium.europa.eu/en/press/press-releases/2018/02/27/eu-emissions-trading-system-reform-council-approves-new-rules-for-the-period-2021-to-2030/pdf, (accessed 30.7.2018)

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CLIMIT programme). The CATO programme office and secretariat has the responsible for knowledge transfer, reporting and dissemination activities. Hydrogen innovation support is undertaken through an integrated and regional approach to decarbonisation as summarised in the next section.

C.2 Policies for H_2 and CCUS Delivery

The Netherlands is committed to decarbonising energy intensive sectors of the economy and has an on-going interest in hydrogen and CCUS technologies as options to reduce dependency on fossil fuels, improve air quality, and create new industries and activities for the green economy. A policy mechanism known as the "Green Deal" is a programme of public-private agreements to facilitate specific actions (such as zero emission public bus transport). A Green Deal "Regional Hydrogen" for studying hydrogen transport through the Gasunie network was agreed in 2016. Key strategic sectors for the Netherlands are large-scale hydrogen production and low emissions transport using hydrogen fuel cells and alternative transport fuels. The government has a number of fiscal measures and support schemes to encourage hydrogen activities and market take-up of zero emission vehicles and fuel cell systems.

On the international stage, the Netherlands is a member of The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), the IEA Hydrogen Implementing Agreement (IA-H_2), the IEA Hybrid Electric Vehicle Implementing Agreement (IA-HEV), IEA Electric Vehicle Initiative (IEA-EVI), Fuel Cells and Hydrogen Joint Undertaking (FCH-JU), and the Carbon Sequestration Leadership Forum (CSLF). The Netherlands is also a member of the North Sea Basin Taskforce (NSBTF), a forum for government and CCS stakeholder representatives to exchange ideas and develop plans for CCS infrastructure in the North Sea Basin.

The Netherlands has a flagship programme known as the National Hydrogen Platform (NWP) for public-private cooperation with the objective of promoting the use of hydrogen in a low carbon economy. Activities are focussed on:

1. Integrating initiatives individual members and sectors;
2. Addressing obstacles to transformation and deployment of H_2; and
3. Coordinating actions and new initiatives

Members of the platform include the Ministry of Infrastructure and the Environment, automotive industry, chemical industry and refineries, gas production companies, and ports. It comprises four task forces:

1. Sustainable hydrogen economy and safety;
2. Infrastructure for mobility;
3. Buses; and
4. Commercial vehicles and trucks.

CCUS policy has been updated with a 2017 Dutch Coalition Agreement on energy policies for 2017-2021. Key relevant aspects are:

1. Support for industrial and waste CCS and a Port of Rotterdam (PoR) low carbon transition originally with an ambitious target of a total 20Mtpa CO_2 emissions reduction by 2030. This target has since been reduced to 7.2Mtpa CO_2. The government will engage with PoR to accelerate uptake of CCS during this period. The preferred business model is for the private sector to invest in capture facilities and the public sector to be responsible for transport and storage;

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2. The closure of two coal fired power stations by 2030, which will reduce CO_2 emissions by 4Mtpa. These assets may be converted to low/zero carbon fuels such as H_2 blended with other gases;
3. The long-standing feed-in tariff system, the SDE+, will be expanded to include new emission reduction technologies, and CCS is highlighted explicitly;
4. €4B per year has been pledged to support the energy transition.

D SWITZERLAND

D.1 Innovation Policies

Switzerland has a number of R&D and innovation funding schemes in place that are dedicated to energy and climate friendly technologies.

D.1.1 Swiss Competence Centres for Energy Research

Under the Energy Strategy 2050, the Swiss Parliament approved the creation of eight national competence centres (Swiss Competence Centres for Energy Research, SCCER). These centres work on application-oriented research for solutions that can be scaled and deployed by the industry and focus on the following action areas: future energy efficient buildings and districts; efficiency of industrial processes; future electrical infrastructure; storage of heat and electricity; supply of electricity (meaning: base load from renewables, i.e. deep geothermal, CO_2 storage and hydropower); energy and mobility; biomass; and non-technological innovations for the energy transition (policy, regulatory, behavioural, economic).

The objective of the innovation programme is to develop by 2025 a portfolio of tested solutions to deliver Switzerland's so-called *Energy Strategy 2050*. CHF 120 million has been allocated for the second phase for the period 2017 - 2020. Until 2020, in addition to the regular funding budget, CHF 19 million is available for R&D projects in the energy field.

The SCCER-SoE (Supply of Electricity) with a total budget of CHF 12 million includes seven pilot and demonstration projects to demonstrate the feasibility of new solutions prior to market implementation. Carbon capture will be evaluated within this EU/Swiss Federal Office of Energy (SFOE) funded project ELEGANCY and the results will be used to initiate with the SFOE a first CO_2 sequestration pilot project by 2019 (as part of WP5). This project builds on the CARMA project (2008-2012), which explored the potential and feasibility of deployment of CCS in Switzerland and looked at developing new CCS technologies and competence for application internationally.

The SCCER Heat and Electricity Storage with a total budget of CHF 11 million includes a thematic focus area on hydrogen production and storage. H_2 production by electrolysis is being investigated with the purpose of enabling, together with inexpensive and safe storage systems, a hydrogen economy. Demonstration projects are planned in Switzerland together with key industry partners.

D.1.2 Technology Guarantee Fund

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The Technology Fund of the Swiss Federal Office for the Environment (FOEN) provides loan guarantees to Swiss companies developing innovative products contributing to a sustainable reduction in greenhouse gas emissions. The Fund is a political instrument of the Swiss government's climate strategy and has a legal basis in the Swiss CO_2 Law. Guarantees may amount to up to CHF 3 million and the sum of the guarantees is capped at CHF 500 million. To date, no guarantees have been provided to businesses active in the H2-CCS field but this mechanism has the potential to also support innovation in that sector.

D.1.3 Promotion of Technology and Innovation

Innosuisse is the Swiss Innovation Promotion Agency. As a federal entity, it is tasked with promoting science-based innovation in the interests of industry and society in Switzerland. In addition to its mandate of managing the energy R&D program SCCER, Innosuisse supports entrepreneurial and start-up activity across the clean energy and climate mitigation sectors.

Under the heading CleanTech, the Swiss Federal Office of Energy (SFOE) also supports a number of pilot, demonstration and key projects to facilitate the introduction of new technologies to the market – in the field of energy efficiency and renewable energy.

At a regional level, Swiss Cantons run innovation promotion programmes through cantonal agencies and provide funding and support to select projects/companies in sectors including energy and climate.

D.2 Policies for H_2 and CCUS Delivery

D.2.1 Energy Strategy 2050

In 2007, the Federal government developed its energy strategy around four main themes: energy efficiency, renewable energy, replacement and construction of the existing large power plants for electricity production, and external energy policy. In 2011, following the earthquake in Japan and nuclear incidents, the Council voted for the withdrawal from nuclear production and subsequently developed the Energy Strategy 2050 (Energiestrategie 2050). This pursues the 2007 Energy Strategy with a focus on energy efficiency, exploiting the potential of hydro power and the new renewable energy technologies (solar, wind, geothermal and biomass), but now includes the closure of the five existing nuclear plants at the end of their technical operating life without replacement.

After a revision of the Energy Law and changes of other federal laws, the Parliament and then Swiss voters approved the revision of the Energy Act in May 2017 and the go-ahead for the first series of measures to restructure the country's energy system. These include:

1. Building Energy Efficiency: this now includes a subsidy programme to encourage the renovation of the existing buildings stock to improve their energy efficiency and tax breaks for the complete demolition and rebuilding of new ones.
2. Renewable Energies: the Energy Strategy 2050 now allows for feed-in remuneration tariff for up to 5 years for solar, wind, geothermal and biomass installations, one-off investment subsidies for small PV systems of less than 30 kW, and financial support to existing hydro

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plants to compensate for depressed power prices. The approval procedures have also been shortened and simplified.

3. Nuclear: indefinite ban on new nuclear plants and export of spent fuel rods outside Switzerland for reprocessing.
4. Transport: tightening of emission specifications (in-line with EU emission limits).
5. Electricity Grid: acceleration and simplification of the legal procedures to facilitate the upgrade and renewal of the electricity network to cope with the new energy system Competitive Tenders.

Carbon capture and storage can support the Energy Strategy 2050 by its application to gas fired power stations, to steam methane reforming in the production of hydrogen for mobility or heating, and to Direct Air Capture. CCS can also support enhanced geothermal power generation technologies.

Switzerland is a member of relevant major international multilateral bodies dealing with H_2 and CCUS such as the IEA IA-H2, IEA IA-HEV, IEA-EVI, and IEAGHG.

D.2.2 Swiss Climate Policy

The current climate policy package is in force until 2020 and the revisions to existing legislation for the 2021-2030 period are currently being debated in Parliament. The existing framework aims to deliver reductions in greenhouse gas emissions by 20% till 2020 (base year 1990) and consists of the following measures:

- A carbon tax in the amount of CHF 96 / tCO_2 (status: 2018) is levied on all fossil heating and process fuels. Revenue from the levy is redistributed to the public and the economy (approx. two-thirds) and invested into the building energy efficiency programme (approx. one-third). A small portion (approx. CHF 25 million) is provided to the Technology Fund.
- Large emission-intensive industrial sites are exempted from the CO_2 tax but are required, in return, to participate in the domestic emissions-trading system (ETS). The Swiss ETS involves around 55 installations covering approximately 5 million tCO_2. Industrial sectors covered by the ETS include, among others, pulp and paper, cement, chemicals, aluminium, refining, and electricity production. As of March 2018, the price of the Swiss emissions allowance (CHU) is CHF 8/tCO_2.
- In addition to the tax on heating and process fuels described above, transport fuels imported into Switzerland are subject to a compensation requirement, whereby a fixed percentage of emissions caused by using these fuels in the transport sector are to be compensated through domestic measures. The quota is set to gradually increase over the 2013-2020 period, reaching a compensation requirement of 10% of CO_2 emissions from imported fuels in 2020. In total, approximately 6.5 million tCO_2 are to be compensated over the 2013-2020 period. As a result, a mechanism for domestic emission reduction projects exist, akin to the CDM mechanisms under the Kyoto Protocol. Carbon sequestration is presently not allowable under this mechanism and continues to be excluded in the currently debated draft version of the new post-2020 legislative package.

For the timeframe post-2020, the legislative environment is currently uncertain, but the proposals under negotiation would call for maintaining the existing policy mechanisms and reinforcing

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commitment to climate change mitigation. If approved, the 2030 target would be a 50% reduction in greenhouse gas emissions to be achieved through domestic – but also to some extent international – measures. After 2050, Switzerland aims to be climate-neutral. While no specific H2 or CCS policies are in place, these innovative approaches could support the achievement of the stated goals.

E UNITED KINGDOM

E.1 Innovation Policies

The UK government provides research and innovation funding through Research Councils, Innovate UK, government departments, grants and the market regulator Ofgem, amongst others. Current relevant support schemes for Hydrogen and CCUS innovation, research and knowledge transfer include:

1. Ofgem: Network innovation: RIIO-GD1 (Revenue=Incentives+Innovation+Outputs), a performance-based model for setting the gas distribution network companies' price controls, lasting eight years from 2013 to 2021.
    a. Gas Network Innovation Competitions (NIC) (up to £20 million/pa) for hydrogen blending; 100% H_2; CV treatment for billing;
    b. Network Innovation Allowance (NIA) is a set allowance each RIIO network licensee receives as part of their price control allowance for smaller projects and preparation of submissions for the NIC;
2. InnovateUK: runs funding competitions across a broad suite of relevant technologies;
3. Synnogy: manages the UK Hydrogen and Fuel Cell Association and delivers projects for the Knowledge Transfer Network on fuel cells and hydrogen;
4. UK H2Mobility: "a collaborative project evaluating the potential for hydrogen FCEVs to provide environmental and economic benefits to the UK" with government department and industry collaboration;
5. UK Government £25 million funding support for the Leeds H21 Project Office and feasibility studies in key areas of the natural gas-to-H_2 conversion roadmap;
6. UK Government grants to Tees Valley Unlimited for studying the cluster decarbonisation using CCS;
7. UK Government funding of UKCCSRC, a distributed centre with membership comprising universities and the British Geological Survey, and associate non-academic membership;
8. Scottish government support for SCCS, a distributed centre of Scottish universities and the British Geological Survey;
9. Innovation priorities contained within the Clean Growth Strategy 2017 and Industrial Strategy 2017 include some funding areas relevant to CCUS and H_2 (highlighted below).

E.2 Policies for H_2 and CCUS Delivery

In Autumn 2017 the UK Government published major policy manifestos for clean economic growth and industrial strategy. These policies reset the focus for creating green economic growth and achieving legislated climate targets against the backdrop of leaving the EU. They contain ambitious technology innovation and both domestic and international market growth strategies based on collaboration between the public and private sectors, and a shift to a whole system view of energy with an objective to identify and leverage cross-sector synergies.

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From the perspective of H_2 and CCUS markets and networks the background against which these new policies are set comprises:

1. The UK Gas Iron Mains Replacement Programme commenced in 2002 and to be completed by 2032, is replacing 100,000 km low-pressure iron distribution and attached service pipes near buildings with polyethylene pipes for safety reasons;
2. The UK Office for Low Emissions Vehicles (OLEV) is providing funding "to position the UK at the global forefront of ULEV development, manufacture and use" and runs a Hydrogen for Transport Programme (public refuelling infrastructure and hydrogen fuel cell vehicles);
3. The UK is a member of relevant major international multilateral bodies dealing with H2 and CCUS such as the IPHE, IEA IA-H2, IEA IA-HEV, IEA-EVI, FCH-JU, IEAGHG, CSLF, and NSBTF;
4. The Scottish Energy Strategy Draft 2017 supports development of H_2 and CCUS;
5. The Scottish Low Carbon Infrastructure Transition Programme runs through until December 2018 with £33 million of European funding support;

E.2.1 The Industrial Strategy Nov 2017 [87]

The following list comprises a high-level summary of relevant elements of the UK Industrial Strategy:

a. The industrial strategy identifies clean growth as one of the four biggest challenges for the UK and therefore embeds this strategy released in October 2017 (described below);
b. Recognises the need to "work with industry to stimulate further market investment in clean and efficient technologies and process", and re-affirms £162 million of innovation funding contained in the Clean Growth Strategy;
c. Support for "smart" energy systems to "link energy supply, storage and use, and join up power, heating and transport to increase efficiency";
d. New technologies for greater storage of electricity and demand management are another focus area;
e. The government is aiming to encourage local smart grids in order to facilitate decarbonisation of the heating and transport sectors;
f. Zero emission transport is a high priority, including vehicle manufacture and supply chains. Although an initial focus is on supporting further electric vehicle charging infrastructure, hydrogen and CCS are mentioned as long term options also with a link to domestic shale gas production.

E.2.2 Clean Growth Strategy Oct 2017[88]

Relevant elements for H_2-CCS extracted from the strategy include:

[87] UK Department for Business, Energy & Industrial Strategy, (2017) https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-futurehttps://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future, (accessed 30.7.2018)

[88] UK Department for Business, Energy & Industrial Strategy, (2017), https://www.gov.uk/government/publications/clean-growth-strategyhttps://www.gov.uk/government/publications/clean-growth-strategy, (accessed 30.7.2018)

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a. Demonstrate international leadership in carbon capture usage and storage (CCUS), by collaborating with global partners and investing up to £100 million in leading edge CCUS and industrial innovation to drive down costs [*This is still focussed on technology cost reduction rather than economies of scale and multi-sector synergies – more detail will be provided in 2018*];
b. Work in partnership with industry, through a new CCUS Council, to put the UK on a path to meet its ambition of having the option of deploying CCUS at scale, and to maximise its industrial opportunity [*Creation of a Cost Challenge Taskforce, which delivered a report to Government in July 2018 entitled "Delivering Clean Growth: CCUS Cost Challenge Taskforce Report"]*;
c. Develop a strategic approach to greenhouse gas removal technologies, building on the Government's programme of research and development and addressing the barriers to their long term deployment [*Some such as air capture would likely require CCUS*];
d. Invest around £162 million of public funds in research and innovation in Energy, Resource and Process efficiency, including up to £20 million to encourage switching to lower carbon fuels [*This includes transforming manufacturing and heavy industry side by side with CCUS – hydrogen is a focus fuel*];
e. Invest in low carbon heating by reforming the Renewable Heat Incentive, spending £4.5 billion to support innovative low carbon heat technologies in homes and businesses between 2016 and 2021;
f. Invest around £184 million of public funds, including two new £10 million innovation programmes to develop new energy efficiency and heating technologies to enable lower cost low carbon homes [*Includes the £25 million programme looking at converting networks from NG to H_2. Side by side with £195 million from Ofgem for gas network companies to introduce new technologies and operating/commercial arrangements. Review studies to be completed end 2017 and government position published mid 2018*];
g. Spend £1 billion supporting the take-up of ultra low emission vehicles (ULEV), including helping consumers to overcome the upfront cost of an electric car [*Primarily focussed on EVs but some HFC funding including a new £23 million for H_2 refuelling infrastructure*];
h. Announce plans for the public sector to lead the way in transitioning to zero emissions vehicles;
i. Invest around £84 million of public funds in innovation in low carbon transport technology and fuels [*£246 million earmarked for development and manufacture of electric batteries*];
j. Phase out the use of unabated coal to produce electricity by 2025;
k. Target a total carbon price in the power sector, which will give businesses greater clarity on the total price they will pay for each tonne of emissions;
l. Invest around £900 million of public funds, including around £265 million in smart systems to reduce the cost of electricity storage, advance innovative demand response technologies and develop new ways of balancing the grid.

F GERMANY

F.1 Innovation Policies

The main source of innovation funding for hydrogen and fuel cell technologies is the "National Hydrogen and Fuel Cell Technology Innovation Programme" (NIP), which was launched in 2006 and is now being continued as NIP2 for another ten years (2016-2026). This is a major programme to support the implementation of the Energy Concept of September 2010 (see section 8.2). It is

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funded by the Federal Ministry for Economic Affairs and Energy ("BMWi") and is focused not only on research and development of technologies which are not yet ready for market but also on the market activation for technologies which have reached market maturity but are not yet competitive in the open market. NIP2 will support the development of the infrastructure for those technologies and the tools and measures to deploy them in the market. The implementation of the NIP2 programme is managed and coordinated by NOW GmbH (National Organisation Hydrogen and Fuel Cell Technology).

The Federal Ministry of Transport and Digital Infrastructure (BMVI) has set its programme within NIP2 and has budgeted to spend €250 million through until 2019 to support hydrogen and fuel cell technology. This includes funding for R&D (funding guidelines published in September 2016) and for market activation measures (funding guidelines published in February 2017) where it funds hydrogen-fuelled vehicles, the commercial development of a hydrogen station network, systems to produce hydrogen by electrolysis systems, non-stationary fuel cells, CHP systems and off-grid power supply. In late 2016 BMWi launched a seventh Energy Research Programme which covers the entire energy chain and a funding programme to subsidise the introduction of residential CHP-fuel cell units (up to <5kW).

In addition, BMVI has budgeted a total of €300 million of funding for the period 2017-2020 for the "Development of Recharging Infrastructure" with the aim to install at least 15,000 recharging stations. It also funds the "Electromobility Model Regions" programme to advance the integration of electric transport in every day life.

Most federal states also have initiatives and funding programs for hydrogen innovation and market development. For example, North Rhine-Westphalia has funded 85 projects since 2000, Hamburg funds the Centre for Innovation hySOLUTIONS, Baden-Wurtemberg funds the innovation agency e-mobil BW, Bavaria has WIBA, the Coordination Centre of the Bavarian Hydrogen Initiative.

F.2 Policies for H_2 and CCUS Delivery

F.2.1 The Energy Concept and the Energy Transition (EnergieWende)

In September 2010, the German government launched with full legislative support the Energy Concept and related Energy Transition, Germany's long term vision for their energy mix and strategy how to achieve it with the objective to become a leading energy-efficient and environmentally sound economy in the world whilst maintaining international competitiveness. The EnergieWende defines a German energy supply system, which is 100% based on renewable energy in the year 2050 and is characterised by the following key points:

1. Energy supply from a range of renewable energy sources to guarantee supply reliability;
2. Focus on improved energy efficiency
3. Electricity is central to energy supply
4. Use of chemical carriers such as hydrogen derived from renewable electricity to store energy
5. Transport based on electricity or hydrogen converted into electricity
6. European interconnected electricity network
7. Significant contribution from biomass and solar heat

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According to the EnergieWende, GHG emissions will reduce steadily by 40% by 2020 and 80-95% (relative to 1990 levels) by 2050. In order to achieve such challenging targets, primary energy consumption will reduce by 50% with an increase in energy efficiency of 2% and renewable energies will gain an increasing share in the primary energy supply of 60% by 2050.

Six months later, following the earthquake and Fukushima nuclear incident in Japan in March 2011, the Government revised the EnergieWende in a cabinet decision on 6th March 2011 to remove nuclear power as a bridging energy technology and decided to phase-out nuclear power generation by 2022.

After the 2013 federal elections, the new coalition government continued to pursue the EnergieWende with only minor changes to the goals.

Over the years, the German energy policy has been amended by further decisions of the Bundestag and European rules but the guiding principles remain the compatibility between environmental protection, security of supply, and affordability. The focus is on the main objectives of increasing the share of renewable energy whilst reducing energy consumption and using energy more efficiently. These objectives are governed by targets for the three main sectors of electricity, heating, and transport and monitored regularly to track progress.

In July 2016, the German government adopted three major pieces of legislation in order to create a consistent framework for a greater share of renewable energy including measures to improve the electricity market, facilitate a digital infrastructure to connect electricity consumers and producers, and revisions of the Renewable Energy Sources Act.

F.2.2 Germany Climate Energy Action Plan

Following the commitments made in the 2015 Paris Agreement on Climate Change and subsequent consultations with the states (Länder), municipalities, associations and citizens on proposals to decarbonise the Germany economy, the German government adopted the Climate Action Plan 2050 in November 2016.

This Climate Action Plan complements the existing targets set out in the EnergieWende with further contributions in line with the commitments made in the Paris Agreement. It is a strategy for the environmentally sound modernisation of the German economy which provides guidance, strategic measures, sectoral milestones and targets for all the areas of energy transformation (energy, buildings, transport, trade and industry, agriculture and forestry) and for the related investments until 2050, but particularly for the period up to 2030.

Similar to the UK, the German government is focusing support on technology innovation without clear preferences to allow the multiplicity of transitional energy pathways to develop competitively whilst aiming to avoid stranded investments.
Key strategic measures included in the Climate Action Plan 2050 are:

1. Overall structural change: A commission made up of a broad range of stakeholders to facilitate structural change, investments and financing for the new energy system.

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2. Buildings: development of further energy standards and focus on heating systems based on renewable energy sources.
3. Transport: development of a climate strategy for road transport including infrastructure.
4. Industry: focus on R&D with industry to reduce GHG emissions from industrial processes, which will include industrial carbon capture and utilisation (CCU).
5. Agriculture: focus on the use of fertilisers to ensure that the target value of 70 kilogram of nitrogen per hectare (as defined in the German National Sustainable Development Strategy) is achieved by 2032.
6. Forestry (and land use): focus on the preservation and improvement of carbon sequestration through carbon sinks in forests with consideration for expansion of Germany's forests.
7. Tax and Economic Incentives: review of the existing tax system and economic stimulus/incentives to positively encourage polluters to reduce their carbon footprint.

Hydrogen as an energy carrier has a place in the German strategies but primarily from renewable electricity and electrolysis. On the other hand, CCS has a low profile within the EnergieWende and the Climate Action Plan 2050. It has met widespread opposition in Germany, mainly against CO_2 storage. EU member states were obliged to translate the 2009 EU Directive on CCS into national laws by 25 June 2011. It took until June 2012 for Germany to do so, though this was reached by a compromise in the end where CO_2 storage is allowed up to a maximum of 1.3 million tonnes every year, with a maximum storage capacity of 4 million tonnes and individual states retaining sovereignty over the authorisation for any carbon storage projects.

Some experts believe that the 2050 objectives and targets of lowering industrial emissions, developing new low carbon processes and developing the circular economy based entirely on renewable sources of energy and feedstocks may not be achievable in the timeframe. The economics of industrial CO_2 utilisation are leading to rethinking of capture and utilisation economics with the possibility of exporting CO_2 for storage via the Netherlands or German North Sea ports. Federal policies have still to recognise these possibilities as part of the EnergieWende.

Germany is a member of relevant major international multilateral bodies dealing with H_2 and CCUS such as the IPHE, IEA IA-H2, IEA IA-HEV, IEA-EVI, FCH-JU, CSLF, and NSBTF.

G NORWAY

G.1 Innovation Policies

The Norwegian government supports a large amount of research and development in energy technologies associated with petroleum, low carbon and renewable energy. Funding is channelled to research institutes such as SINTEF (a large organisation with an emphasis on energy technology innovation) and IRIS (partly owner by the University of Stavanger with focus areas of EOR, drilling, and marine environment), universities, and collaborations with the private sector. Programmes are currently implemented within a 10-year framework (which commenced in 2013) known as ENERGIX to match the overall Norwegian clean energy strategy Energi21 (National Strategy for Research, Development, Demonstration and Commercialisation of New Energy Technology) with the objective of delivering economic and climate benefits.

The principal body for financing innovation research and development is the Research Council of Norway (RCN or Forskningsrådet). Key funding initiatives relevant to H_2 and CCS are:

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1. The CLIMIT research programme for CCS 2017-2022 administered jointly by RCN and Gassnova with an objective of supporting research, development, demonstration (pilot) and commercialisation;
2. Eight Centres for Environment-friendly Energy Research (FME) 2017-2025, each funded up to NOK 25 million (€2.5 million), with a portfolio including environment-friendly transport, CO_2 management (CCS), biofuels and zero-emission urban zones. These centres are joint ventures between RCN, industry, and national and international research bodies (including universities and institutes):
    a. The Norwegian CCS Research Centre. SINTEF Energy Research is the host institution;
    b. Mobility Zero Emission Energy Systems. Focus on land and sea transport, including use of hydrogen and batteries, and business models for zero-emission transport. The Institute for Energy Technology (IFE) is the host for this centre.

G.2 Policies for H_2 and CCUS Delivery

The high-level Norwegian strategy for H_2 and CCS is to facilitate the removal of European CO_2 emissions whilst ensuring a sustainable future for the Norwegian economy with its large petroleum resource base and product exports. Successive Norwegian governments have continued programmes aimed at achieving this objective, designing and implementing Hydrogen and CCS Strategies supported by a variety of policies and fiscal measures to facilitate the energy transformation and encourage both domestic and international take-up of low carbon and renewable energy under the Energi21 strategy. Ultimately these activities are expected to synergistically create new export markets for Norwegian technology and skills.

The Norwegian government introduced a Hydrogen Strategy in 2003 and subsequently in 2005 appointed the Norwegian Hydrogen Council to advise Ministries, create action plans and oversee coordination of all of Norway's efforts to increase the country's use of hydrogen as an energy carrier. The Secretariat of this "Norwegian Hydrogen Platform" was based at The Research Council of Norway. As noted above RCN continues to fund hydrogen innovation activities. Specific delivery activities and targets for hydrogen refuelling stations and HFCEVs (buses and a small fleet of demonstration vehicles) are limited to regional strategies such as Oslo city and Akershus County (surrounding Oslo).

The 2017-18 Budget Proposal submitted to the Storting (parliament) in Autumn 2017 summed up the CCS policy manifesto at the time of writing. The following is a translation of relevant aspects:

1. The overall goal of the government's CO_2-handling policy is to help CO_2 management become a cost-effective measure in the work against global climate change. Work on CO_2 handling will help to develop and demonstrate cost-effective CO_2 capture and storage technologies with a potential for proliferation. In order for the goal of CO_2 management to be achieved, technology development and cost reductions are necessary, including through the construction of full-scale demonstration facilities.
2. The Government presented its strategy for the work on CO_2 handling in Prop. 1 S (2014-2015) for the Ministry of Petroleum and Energy. The measures in the strategy include research, development and demonstration and the efforts to realize full-scale projects with dissemination potential. Full-scale demonstration facilities include capture, transportation, storage or alternative use of CO_2. The strategy also includes international efforts to promote CO_2 handling.

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3. Full-scale CO_2 handling in Norway has been investigated and followed up through several studies, including the 2015 idea study and the feasibility studies that were presented in 2016. Based on the results of the feasibility study, it was decided to continue the planning work, cf. the Ministry of Petroleum and Energy's Prop. 1 S (2016-2017). Gassnova has awarded contracts for concept studies with option for pre-design for CO_2 capture and storage. Three industrial players, Norcem, Yara and Klemetsrudanlegg, will deliver their concept studies in the autumn of 2017. Gassco has awarded contracts for conceptual studies of ship transport of CO_2 to Larvik Shipping and Brevik Engineering. These studies will also be completed in the autumn of 2017. Statoil has been awarded a contract for concept studies of CO_2 storage. Concept selection for the storage part of the project is scheduled for summer 2018.
4. Concept studies will, among other things, provide updated cost estimates for capturing and transporting CO_2, better understanding of the risks in the various projects and thus also an overall picture of the state's costs and risks. At the same time, the companies, Gassnova and the Ministry of Petroleum and Energy are working on analysing the usefulness of the project. The main objective of the project is to contribute to learning and cost reductions for subsequent CO_2-handling projects. This will provide new information on both costs and benefits in a full-scale CO_2-handling project in Norway in the concept studies. The Government wishes to submit this information to the Storting before it is decided to continue the full-scale project. The Government will therefore return to the Storting with a comprehensive presentation of the work on full scale CO_2 handling in Norway after the results of the concept studies on capture have been reviewed, most recently in connection with the revised National Budget in 2018. The Government will also assess the contribution of industrial companies, incentives to cost reductions, and the state's total costs and risks as well as the potential for cost reductions and technology dissemination to projects internationally.
5. Mongstad Technology Centre is a facility for the development, testing and qualification of CO_2 capture technologies, and contributes to the international dissemination of these experiences, thus reducing costs and risks for full-scale CO_2 capture. The main objective of the technology centre is to contribute to technology development for increasing the spread of CO_2 capture globally. The state, Statoil, Shell and Total have continued operations at the Mongstad (TCM) Technology Centre for CO_2 capture, initially for three new years after the expiry of the current agreement in August 2017, cf. Prop. 129 S (2016-2017).
6. The Government will continue to pursue research and development of CO_2 handling technologies. The strategy includes a continued commitment to CLIMIT, research centres for environmentally friendly energy and international research activities. CLIMIT is a national program for research, development and demonstration of technologies for capture, transport and storage of CO_2 from fossil-based power generation and industry.
7. 2017-18 National Budget Proposal - grants totalling NOK 509 million (€52 million) for the work on CO_2 handling, including:
    a. NOK 195 million for further operation at the Technology Centre for CO_2 capture at Mongstad (TCM). The grant shall cover the state's share of operating expenses at the facility;
    b. NOK 182.5 million to CLIMIT. The program provides support for research and demonstration of technologies for CO_2 handling;

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c. NOK 107 million in administration grants to Gassnova SF, which takes care of the government's interests related to CO_2 handling, including the conservation of the state's stake in the Mongstad Technology Centre for CO_2 capture;
d. NOK 20 million for planning full-scale CO_2 handling in Norway.

Further to points 3 and 4 above, in May 2018 the government announced an additional budget of NOK 80 million to progress the Front End Engineering and Design (FEED) for the capture facility at the Norcem cement plant, transport and storage, and a possible second capture facility.

Norway is a member of many international multilateral initiatives dealing with H_2 and CCUS including IPHE, IEA IA-H2, IEA-EVI, FCH-JU, IEAGHG, and CSLF.

H CARBON MARKETS OVERVIEW AND OUTLOOK

Ever since their inception, international carbon markets can be characterized as constantly evolving and, at times, as very volatile markets. International and domestic political decisions can create, alter or even end markets in a very short span of time. In the last 20 years, multiple local and inter-regional ETS have been implemented, extended and fine-tuned by regulatory authorities, with one example being the European Emission Trading System (EU-ETS). Regarding carbon offsets, the Kyoto Protocol laid the foundation for establishing an international market mechanism, i.e. the Clean Development Mechanism (CDM). The chapter will first describe the creation and intention of the CDM mechanism and explain the typical CDM process cycle. In a second part, the development of market volumes and prices will be analyzed in greater detail.

H.1 CDM mechanism

The main driver in climate finance until 2020 is the Clean Development Mechanism (CDM), which was defined in the Kyoto Protocol (IPCC, 2007). It lays the foundation for emission reduction projects that generate certified emission reduction units (CERs) which can be bought, retired or used and traded in emissions trading schemes.

Article 12 of the Protocol divided countries in Annex I and Non-Annex I parties. Annex I parties are all the countries listed in Annex I of the treaty, i.e. the industrialized countries. Non-Annex I parties consist of mainly developing countries.

The purpose of the CDM was defined in paragraph 2 and is: *to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments.* Thus, developing countries not included in Annex I would benefit from project activities that result in CERs, while Annex I countries may use these CERs to contribute to compliance with part of their quantified emission limitation and reduction commitments.

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The economic basis for including developing countries in efforts to reduce emissions is that emission cuts are thought to be less expensive in developing countries than developed countries (Goldemberg et al., 1996[89], p. 30; Grubb, 2003[90], p. 159).

H.2 CDM Project cycle

An industrialized country that wishes to obtain credits from a CDM project must secure the consent of the developing country hosting the project and their agreement that the project will contribute to sustainable development. Then, using methodologies approved by the CDM Executive Board (EB), the applicant industrialized country must make the case that the carbon project is additional (i.e. that it would not have happened under a business-as-usual scenario), and must establish a baseline that plausibly estimates the future emissions in the absence of the project. The case is then validated by a third-party agency, called a Designated Operational Entity (DOE), to ensure the project results in real, measurable, and long-term emission reductions. The EB then decides whether or not to register (approve) the project. If a project is registered and implemented, the EB issues CERs to project participants based on the monitored difference between the baseline and the actual emissions. Prior to issuance, this difference needs again third-party verification by the DOE.

H.2.1 Carbon Capture and Storage as CDM Project Activities

The inclusion of carbon dioxide capture and storage (CCS) in geological formations in the CDM has been a source of intense debate at UNFCCC's Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP). Finally, at CMP 7 in Durban in 2011, the Parties adopted modalities for the inclusion of CCS in the CDM. Owing to the staggering deployment of CCS in Annex I countries, the interest to develop CCS in Annex II countries has been virtually nil. Currently, the official online repository for CDM methodologies shows an empty placeholder for approved or proposed CCS methodologies.[91]

H.3 Market prices and volumes

The Clean Development Mechanism gained traction after the establishment of the EU ETS in 2005 and the subsequent entry into force of the Kyoto protocol. EU ETS firms could comply with their regulations by buying offset credits from the CDM. Figure H-1 shows the market development of the CDM and voluntary offset schemes. After highs in 2007 and 2008, prices dropped significantly and in July 2012 a new record low was reached at around €2.50 (a more than 70% drop in one year). The cause for this drop and the subsequently low prices can be found in the oversupply of EU emissions allowances, itself due to a slowing economy after the financial crisis. Oversupply also affected the CDM market as the EU changed its laws concerning the use of CERs in the EU ETS. From the beginning of phase 2 of the EU ETS (2008), CERs were subject to quantitative and qualitative restrictions. Overall in phase 2 (2008-2012), participants in the EU ETS used 1.058 billion tonnes of international.[92]

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[89] Goldemberg, J.; et al. (1996). *Introduction: scope of the assessment. In: Climate Change 1995: Economic and Social Dimensions of Climate Change.* Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change (J.P. Bruce et al. Eds.). Cambridge University Press, Cambridge, U.K., and New York, N.Y., U.S.A.
[90] Grubb, M. (2003). *The Economics of the Kyoto Protocol* (PDF). World Economics. 4 (3): 143–189.
[91] https://cdm.unfccc.int/methodologies/index.html (accessed: 25.07.2018)
[92] https://ec.europa.eu/clima/policies/ets/credits_en (accessed 26.07.2018)

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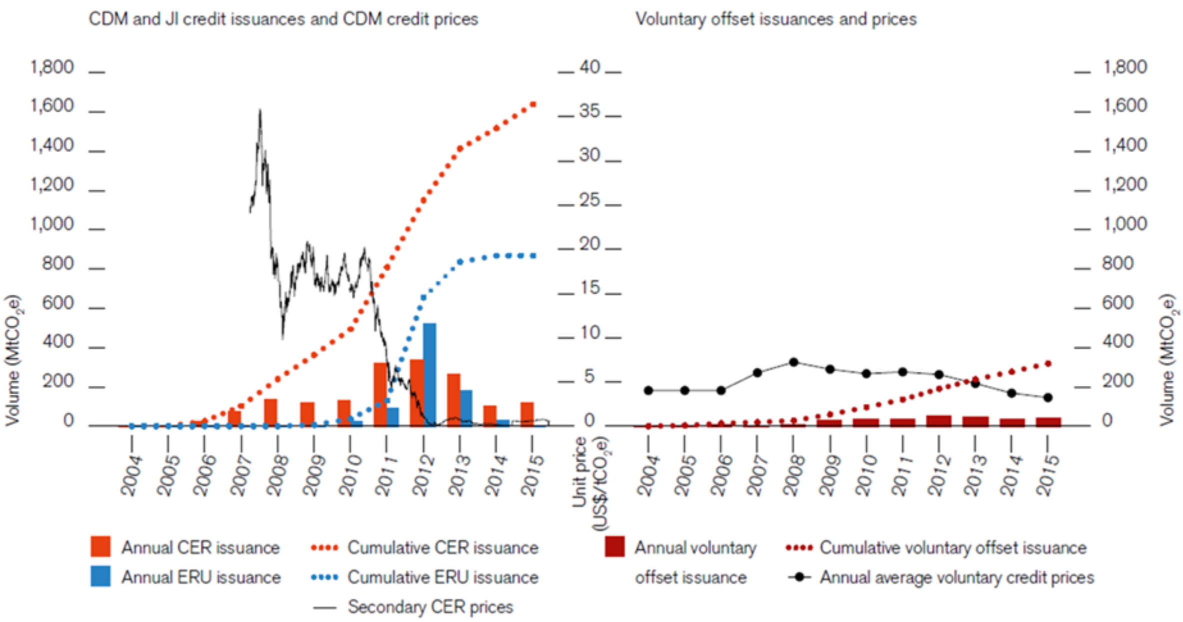

Figure H-1 Carbon credit volume and prices under the Kyoto Protocol and under voluntary market standards. Source: World Bank (2016)

Since the launch of phase 3 in 2013, CERs are no longer compliance units within the EU ETS and must be exchanged for EU allowances. Operators must request this exchange up to their individual entitlement limit set in the registry. Credits issued in respect of emission reduction in the first commitment period of the Kyoto Protocol (2008-2012) had to be exchanged with EU allowances by 31 March 2015. After 2015, hardly any market development took place in the CDM and CER spot and futures prices have remained at the lowest end, i.e. the cost to be paid to the UNFCCC to issue them. As CER vintages after 2012 are no longer accepted in the EU ETS, the CDM lacks the demand needed to foster development of new projects or continued operation of existing ones. Some government sponsored investment programs exist to help projects get restarted. International finance institutions such as the World Bank have also launched results-based finance programs using the CDM as their compliance framework.

H.4 Carbon market outlook

On December 12, 2015, 196 Parties to the UN Framework Convention on Climate Change (UNFCCC) adopted the Paris Agreement, a new legally-binding framework for an internationally coordinated effort to tackle climate change. The Agreement represents the culmination of six years of international negotiations under the auspices of the UNFCCC, and was reached under intense international pressure to avoid a repeated failure of the Copenhagen conference in 2009. The Agreement establishes a global warming goal of well below 2°C relative to the pre-industrial temperature average. It requires countries to formulate progressively more ambitious climate targets, which ought to be consistent with this overarching goal. To this date, 179 parties have ratified the Paris Agreement and on October 5, 2016, the threshold for the entry into force of the Paris Agreement was achieved. Signatory countries (Parties) will meet regularly at the Conference of the Parties serving as the Meeting of the Parties to the Paris Agreement (CMA), taking place as

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part of the yearly COP conventions.[93] The Paris Agreement establishes the obligation for all Parties to develop plans on how to contribute to climate change mitigation in the form of "Nationally Determined Contributions" (NDCs).

H.4.1 NDCs

The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve over a certain time frame. Prior to national ratification, the NDCs are known as 'Intended NDC' or INDC. Parties are to pursue domestic mitigation measures in order to achieve the objectives of such contributions. Some Parties have included reference to CCUS in their first NDC submitted to the Secretariat of the Convention, as summarized in the table below[94].

Table H-1 CCS & CCU mentioned in NDCs

Country	**Excerpts**	**Source**	**Page**
Bahrain	*Carbon Capture and Storage: Bahrain Petroleum Company (BAPCO) Carbon Recovery Plan utilizes Waste CO_2 rich off gas stream which is to be used for industrial applications. Gulf Petrochemical Industries Company (GPIC) Carbon Recovery Project is able to capture CO_2 in the flue gases of the GPIC Methanol Plant.*	First NDC	3
China	*Enhancing Support in terms of Science and Technology: To strengthen R&D and commercialization demonstration for low-carbon technologies, such as energy conservation, renewable energy, advanced nuclear power technologies and carbon capture, utilization and storage and to promote the technologies of utilizing carbon dioxide to enhance oil recovery and coal-bed methane recovery.*	First NDC	13
Egypt	*There are four key technology-related requirements essential for transformation: [...] (ii) carbon capture and storage "CCS" as a technology alternative that can be used in the future if proven economically feasible.*	INDC	11
Iran	*Use of renewable and alternative energy resources (like nuclear power) as well as biofuels, biogas, waste to energy production and CCS.*	INDC	6

[93] UNFCCC website: https://unfccc.int/process/the-paris-agreement/status-of-ratification
[94] http://www4.unfccc.int/ndcregistry/Pages/All.aspx (for NDC), http://www4.unfccc.int/submissions/INDC/Submission%20Pages/submissions.aspx (for INDC, both accessed: 26.07.2018)

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Iraq	تنفيذ مشروع إستراتيجي لإصاياد وتخزي غاز ثنائي اكسيد الكروون في-4 التراكيب الجيولوجية (CCS).	INDC	7
Malawi	*Support industries engaged in carbon capture and storage* Subject to provision of implementation means: *Capacity requirements (CR), technology requirements (TR) and finance requirements (FR)*	INDC	8
Norway	*[…] priority areas for enhanced national climate policy efforts are: […] - CO_2 capture and storage*	First NDC	5
Saudi Arabia	*Carbon Capture and Utilization/Storage: promote and encourage actions in this area. As part of its sustainability programme, the Kingdom of Saudi Arabia plans to build the world's largest carbon capture and use plant. This initiative aims to capture and purify about 1,500 tons of CO_2 a day for use in other petrochemical plants. Saudi Arabia will operate on pilot testing basis, a Carbon Dioxide – Enhanced Oil Recovery (CO_2-EOR) demonstration project to assess the viability of CO_2 sequestration in oil reservoirs and any other useful applications. Forty million standard cubic feet a day of CO_2 that will be captured, processed and injected into the Othmaniya oil reservoir. This pilot project has comprehensive monitoring and surveillance plans. The success of this pilot will determine the extent this program will contribute to the Kingdom's ambition in addressing climate change.* *Research and development activities to provide technologies that enhance economic competitiveness. […] the identification of appropriate technological options, which are consistent with national priorities, and domestic human and financial resources […] (e.g. carbon capture utilization and storage).*	First NDC	3,5
South Africa	*CCS: 23 Mt CO_2 from the coal-to-liquid plant - US$0.45 billion. […] Some technologies that could help South Africa to further reduce emissions that have been identified include: […] carbon capture and sequestration; and advanced bio-energy.*	First NDC	9,10
United Arab Emirates	*The UAE is also developing the region's first commercial-scale network for carbon capture, usage and storage. The project notably captures and compresses emissions at a steel manufacturing facility, which will be compressed and transported to oil fields, where it will be used to enhance oil*	First NDC	2

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	recovery and ultimately be stored underground providing one of the first viable mechanisms to decarbonize essential energy intensive industries.		
(I)NDCs mentioning CO_2 transport and storage under sector coverage			
EU	*Coverage – Sectors/Source Categories – Energy: […] CO2 transport and storage*	First NDC	4
Japan	*Scope – Sectors – Energy – […] CO2 transport and storage*	First NDC	3
Montenegro	*Sectors covered – Energy – […] CO2 transport and storage*	INDC	2

H.4.2 Carbon Markets under the Paris Agreement

Apart from the climate target setting obligation, the Paris Agreement recognizes the possibility of voluntary cooperation ('bottom-up') among Parties to allow for higher ambition. To that purpose, the Agreement sets out principles for cooperation that involve Internationally Transferred Mitigation Outcomes (ITMOs), i.e. bilateral or multilateral transfers of emission reductions. These principles include:

- Participation is voluntary and must be approved by the national government;
- Use of cooperation mechanisms is designed to increase the effort in terms of climate change mitigation or adaptation;
- Cooperation must promote sustainable development, i.e. other factors besides reducing greenhouse gas emissions shall be addressed;
- The mechanism shall ensure environmental integrity

The relevant articles that relate to carbon markets are Article 6.2, 6.4 and to a lesser degree Article 6.8. These are further explained in the following paragraphs. The regulatory framework that will detail the rules of the Paris Agreement, including those for the implementation of Article 6, is currently under development by negotiators of the Parties. The so-called Paris Agreement Rule Book is expected to be finalized and adopted at COP 24 in Katovice, Poland, in late 2018.

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H.4.2.1 Article 6.2: Internationally-transferred mitigation outcomes

Countries can cooperate bilaterally or with a group of countries to transfer emission reduction units (ITMOs) to help achieve and improve their emission targets. This allows for the possibility of emission reduction measures being implemented in one country while the resulting emission reductions are transferred to another country to be counted towards the achievement of its NDC. This requires transparency and a robust accounting system to avoid double counting. While international supervision of these cooperation activities is not foreseen, a work programme was agreed to develop guidelines on using this cooperative approach.[95]

H.4.2.2 Article 6.4: A new market mechanism, also known as the "Sustainable Development" or "Mitigation" Mechanism

This article suggests a new mechanism to support countries in reducing emissions and achieving sustainable development. Known under the working title Sustainable Development Mechansim (SDM), the mechanism will replace the CDM and will therefore likely inherit many of its regulatory features. Most importantly, the new mechanism will be centrally administered ('top-down') by a UNFCCC legal body. The Conference of the Parties will adopt rules, modalities and procedures which must be observed when implementing activities under Article 6.4. The aim is to ensure that standardized procedures are followed in the design, implementation, and verification of emission reduction activities.

As with the cooperative approaches under Article 6.2, the emission reductions achieved can be transferred and counted towards the recipient's NDC. Additionally, the Paris Agreement requires that transactions under Article 6.4 result in raised ambition, meaning that the net global outcome of the mechanism must result in an absolute reduction of global greenhouse gas emissions. In practice, emission reduction projects implemented under Art. 6.4 must be outside the scope of the host country's NDC.

H.4.2.3 Article 6.8: Non-market based approaches, such as technology transfer, capacity building, and climate finance support

As a third option, Article 6.8 provides the grounds for cooperation between countries without using market-based mechanisms. A "framework for non-market-based approaches" will be developed in the coming years.

[95] German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety website: https://www.carbon-mechanisms.de/en/introduction/the-paris-agreement-and-article-6/ (accessed 24.07.2018)

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I CO$_2$ STORAGE DEVELOPER/OPERATOR BUSINESS RISK AND MITIGATION ASSESSMENT

CO$_2$ Storage Business Risk	Possible Mitigation Measures
Market Risks: 1. Market demand declines from, or doesn't meet, projection in investment case 2. Initial or cornerstone customers delayed in start-up and use of transport and storage service 3. Negative effects of dynamics of end use hydrogen markets, electricity markets or industrial product markets	▪ Take-or-pay contract with base-load emitters with sufficient capacity reserved and secured market demand to cover a threshold return on investment. Appropriate pass-through if third party capture provider. ▪ Choose counterparties with secure market demand or business model for a required minimum period ▪ Terms of take-or-pay contracts include public sector underwriting for transport and storage compensation mechanism or revenue support ▪ Public sector market-maker that carries coordination responsibility and is guarantor of last resort ▪ Market regulations extended to include mechanisms to dampen impact on transport and storage operators such as contracts for difference, revenue compensation, capacity payments
Macroeconomic Risks: 1. Carbon price on ETS stays too low for too long to incentivise decarbonisation investments in industry (incl hydrogen production) 2. Growth in new industry/service sectors pulls jobs and skills development away from CCS generally and T&S particularly 3. International climate change efforts fail to address disparity between carbon content of goods and services produced in different regions and jurisdictions resulting in disequilibrium in global markets and disincentives for industry decarbonising	▪ Carbon price floor and/or a new carbon tax increased in line with a credible price trajectory to meet national emissions targets and value the CO$_2$ externality for the economy, with compensatory mechanisms for the disparity between domestic and global markets. ▪ Co-ordinated sector strategies that are consistent with requirements for delivering emissions targets and ensure skills training and education programmes are pro-actively implemented in advance of shortages occurring. ▪ Support measures for industry introduced (including import border adjustment, export price compensation) in accordance with a designed timeline consistent with meeting emissions targets
Financial Risks: 1. Uninsurable components of the transport and storage infrastructure and operations require alternative and novel underwriting and guarantee mechanisms for lenders otherwise finance is unavailable	▪ Public sector underwriting where no insurance available, underwriting beyond limits on carbon pricing (guarantees for capped carbon penalties for geological storage), no-fault compensation mechanisms, guarantor of last resort ▪ Contract with technology suppliers who can provide substantive warranties and guarantees within a

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CO_2 Storage Business Risk	Possible Mitigation Measures
2. New technology/supplier guarantees and warranties will be required by lenders otherwise finance will be unavailable or high cost 3. Lenders seek onerous termination provisions or step-in rights making finance essentially unavailable 4. Lenders conditions incompatible with regulatory regime making finance essentially unavailable 5. Lack of confidence from banks in end user market and viability of long term agreements with emitters	partnership structure under the terms and conditions of a suitable umbrella agreement ▪ Mandate a other public authority to perform step-in functions as part of regulatory oversight including permit/licence suspension or termination. Include cost capping and underwriting minimum repayment thresholds as required in the umbrella agreement ▪ Utilise umbrella agreement to establish required statutory provisions and regulations for private sector finance to be available ▪ Include government/public authority guarantees in an umbrella agreement
Legal & Regulatory Risks: 1. Mandatory third-party access to infrastructure leading to operational and commercial problems such as controlling CO_2 quality specs and inability to meet performance guarantees 2. Inconsistent laws and regulations between end use markets and those governing CCS permitting and operations affect construction and/or service delivery 3. Change of laws/statutes/regulations governing end use markets having a detrimental impact on segment businesses 4. Change of laws/statutes/regulations governing CCS having a detrimental impact on segment businesses 5. Statutory remedies including compensation and penalties for defined and limited events (incl. death) result in expensive insurance for an operator 6. Pipeline consents, permits, leases or licences are not easily obtained (delayed, conditional or not granted due to technical and/or safety uncertainty) 7. Storage permits, leases or licences are not easily	▪ Establish a regulatory regime that governs CO_2 quality specifications rather than leaving it to contractual arrangements ▪ Establish an oversight council including regulators and others to ensure consistency and compatibility of regulations ▪ Establish an oversight council including regulators and others to advise government on the impact of end use market regulation on segment businesses ▪ Establish an oversight council including regulators and others to advise government on the impact of CCS regulation on segment businesses ▪ Proactively work with the insurance industry, regulators and public authorities to characterise the linkages between remedies and insurance products and develop least cost or most efficient solutions for T&S infrastructure operators ▪ Proactively and collaboratively engage early with relevant stakeholders including regulators, local authorities, environment agencies etc. ▪ Proactively and collaboratively engage early with relevant regulators ▪ Proactively develop legal "toolkits" focussed on civil law with experts, regulators and international bodies such as IEA & GCCSI

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CO_2 Storage Business Risk	Possible Mitigation Measures
obtained (delayed, not granted or require onerous conditions for example in monitoring and decommissioning plans) **8.** Prosecuting or defending civil law cases is difficult and expensive due to novelty of storage related activities and no precedents other than analogues in other sectors	
Political Risks: 1. Change in political priorities, policy or supporting mandates related to CCS or the end use markets (e.g. hydrogen market sectors, industrial CO2 utilisation) 2. Successive governments delay dealing with decarbonising trade exposed industries resulting in slow uptake of storage services beyond initial emitters	▪ Long term political and financial commitment to first clean infrastructure project in statute and cross-party consensus on energy policy ▪ Minimise upfront investment and seek joint government funding for engineering studies ▪ CCS infrastructure umbrella agreement between state/public authority and private sector providing loan guarantees, long tenor debt repayment, revenue compensation at agreed threshold
Technology Risks: 1. Pipelines cannot cater for the CO2 transport requirements, e.g. not being able to handle the physical and chemical properties of blended CO2 streams. Results in re-engineering or loss of customers 2. Full chain technical/technology integration and performance don't meet design criteria requiring re-design, remediation, or re-engineering 3. Storage site cannot cater for required dynamics of CO2 stream (includes surface facilities, wells and geological formation) requiring selection of another site 4. Existing MMV technologies are not able to provide necessary data for regulatory compliance purposes	▪ Government compensation for storage operator above agreed threshold ▪ Insurance cover wherever possible ▪ Umbrella agreement including government compensation for storage operator above agreed threshold ▪ Technical collaboration between EPCMs and technology suppliers across the chain to stress-test integrated designs ▪ Umbrella agreement including government compensation for storage operator appraisal and characterisation programme, FEED or detailed design above agreed threshold ▪ Characterise a back-up storage site pre-FID ▪ Regulator/Competent Authority implements flexible or less onerous compliance and site transfer rules

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CO_2 Storage Business Risk	Possible Mitigation Measures
Operational Risks: 1. Negative performance impact on transport and storage operations of upstream emitter or CO2 capture operations 2. Short term geological storage outage: e.g. well closures, injectivity problems, facilities problems, maintenance overruns 3. Underperformance of geological storage site (incl. capacity, lifetime injectivity, migration) 4. Unpredicted behaviour of CO2 plume during post-closure phase causing delays to hand-over to Competent Authority or requiring remediation	▪ Use of proven technology and designs ▪ Supplier guarantees and warranties ▪ Insurance cover ▪ Emitter or capture operator compensation to storage operator ▪ Government compensation for storage operator above agreed threshold ▪ Extended pre-FID appraisal and characterisation period including injection testing, pressure monitoring and 4D seismic surveying ▪ Engineered redundancy in wells and storage formations ▪ Pre-appraised and characterised back-up storage sites prior to FID ▪ Public sector underwriting where no insurance available, underwriting beyond limits on carbon pricing (guarantees for capped carbon penalties for geological storage), no-fault compensation mechanisms, guarantor of last resort for financiers ▪ Pro-actively increased MMV programme to reduce unexpected outcomes ▪ Reduce storage site utilisation factor to minimise plume migration distances and reservoir pressures
Social & Societal Risks: 1. Public attitudes become negative after FID or construction causing underutilisation of the storage facilities and service **2.** Insufficient education and skills training programmes to provide workforce needed across the H2-CCS chain leading to underdevelopment of T&S infrastructure service	▪ CCS infrastructure umbrella agreement between state/public authority and private sector providing revenue compensation at agreed threshold ▪ Ongoing education and engagement programmes to ensure public support ▪ Ensure training and skills development is integral to clean growth and industrial strategies at the sector level

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