Deployment of an industrial Carbon Capture and Storage cluster in Europe: A funding pathway
DEPLOYMENT OF AN INDUSTRIAL CCS CLUSTER IN EUROPE: A FUNDING PATHWAY

Authors:

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The Industrial Innovation for Competitiveness (i24c) initiative is a European platform established by the European Climate Foundation and dedicated to developing and promoting an industrial strategy that secures European industry’s competitive advantage through innovation. It aims to strengthen understanding and confidence in how, through a systemic focus on innovation, Europe’s industries can successfully compete and drive prosperity in the dynamic transition to the new economy, shaped by global technological, social and ecological mega-trends. i24c develops evidence to inform the critical debate on these issues in Europe and works to co-create effective and socially fair solutions with a wide range of partners.

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Element Energy is a leading low carbon energy consultancy working in a range of sectors including carbon capture and storage, low carbon transport, low carbon buildings, renewable power generation, energy networks, and energy storage. Element Energy works with a broad range of private and public sector clients to address challenges across the low carbon energy sector, and provides insight and analysis across all parts of the CCS chain.

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It should be noted that the costs shown in this report for a potential industrial CCS cluster in Rotterdam are illustrative only.

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FOREWORD

I am proud to present the latest instalment in our series of technical studies examining “bottlenecks” on the way to the full decarbonisation of Europe in line with the aims of the Paris Agreement. Attention-grabbing strides have recently been made in the decarbonisation of electricity and transport, where the continued application of cutting-edge technology, systems thinking, long-term investment and economies-of-scale will be central to sustained progress. This has been the subject of two of the earlier studies in this series.*

Notwithstanding the progress in other sectors, there is now a striking degree of consensus that much larger strides are needed if we are to decarbonise Europe’s Resource and Energy-Intensive Industries (REIs), which are collectively responsible for around 20 per cent of Europe’s emissions and whose products are indispensable to the low carbon transition we need. Without doubt, Industrial Carbon Capture and Storage (ICCS) will have a role to play here, alongside innovative circular materials design and resource and energy efficient manufacturing processes, in helping many of these industries to reduce their emissions, at scale, as cost-effectively a possible while creating sustainable, well-paid employment.

But it is becoming urgent that progress speeds up, to enable ICCS to make a full contribution to European decarbonisation in the short-term. And this requires concerted action now.

The aim of this report is to examine whether current EU and national funding mechanisms are “fit for purpose” when it comes to providing the finance ICCS clusters need – as soon as possible. With the support of Element Energy, we have identified a funding pathway which could see Europe’s first ICCS cluster becoming operational by as soon as 2021. In what follows, we describe this pathway and make detailed suggestions for what key stakeholders should do, to ensure successful deployment.

With long investment cycles, attracting finance remains a major hurdle to ICCS projects. Our analysis confirms that adopting a cluster approach (rather than one based on individual projects) has the potential to deliver by far the best value, as well as securing the volumes of CO₂ required to make storage development viable.

The prize is potentially huge. Having assessed the key requirements of a potential ICCS cluster, using The Port of Rotterdam (one of Europe’s largest industrial clusters) as an illustration and guide, we find that a cluster of this scope could store over 30 million tonnes of CO₂ by 2035. And it could get started within five years, given the right support. This would bring huge spillover benefits for industrial decarbonisation in the Netherlands and across Northern Europe in general.

The 2020s will be a make-or-break decade for so many aspects of the low carbon transition. CCS in industrial plants needs to be part of the picture. Getting the financing right is clearly an essential first step. But we also need to establish the right frameworks for shared liability between operators and tackle some of the concerns the public and some policymakers still harbour over industrial CCS. This report shows the way for at least one of the hurdles related to CCS. I hope you enjoy reading it.

Dr Martin Porter
Executive Director
The Industrial Innovation for Competitiveness initiative (i2-4c)

*Scaling up innovation in the energy union to meet new climate, competitiveness and societal goals (2016), i24c with support from Capgemini Consulting; Driving innovation in the automotive value chain (2016), i24c with support from Ricardo Energy & Environment
**EXECUTIVE SUMMARY**

**1. Industrial CCS clusters are key to European industrial decarbonisation**

Carbon Capture and Storage (CCS) is a key to Europe reaching the Paris Agreement objectives of net zero emissions by 2050, and to deeply decarbonise European energy-intensive industry. This report argues that there is a clear value proposition in building CCS projects around industrial clusters, rather than considering site-by-site decarbonisation options. Development of CCS projects as “clusters” and shared transport and storage infrastructure can reduce cost and risk for multiple industrial emitters, which are often located close to each other (e.g. near ports).

Industrial CCS can also play an instrumental role in retaining the existing energy-intensive industries, which currently employ more than 1 million people in Europe, by mitigating the long-term carbon price risk. The availability of CCS could reduce the cumulated energy system costs by more than €1 trillion in the EU by 2050 alone and in the longer term, and as European countries move towards net zero emissions, the value of CCS is expected to further increase to more than €50 billion per annum.

Element Energy and i2-4c have sought to develop a funding pathway combining existing and future European funds and other financing instruments to leverage private investment and successfully deliver at least one industrial CCS cluster in Europe. Over a period of six months and with significant input from European CCS stakeholders, the project has assessed the key requirements of a potential industrial CCS cluster using Rotterdam as an illustrative starting point. On that basis, we have suggested specific actions for various stakeholders in order to successfully embark on this pathway and identified key messages for cluster development across Europe using Rotterdam as a case study.

**2. The first industrial CCS clusters in Europe can be operational in the early 2020s**

Storage appraisal is the first activity of any CCS project, and is a precondition for further progress. The first industrial CCS clusters in Europe, which already have access to proven storage capacity, can be operational by the early 2020s.

Once the proven storage capacity is available, industrial CCS clusters can be developed in phases:

- Phase 1: The first phase of this project would involve the installation of an onshore backbone pipeline and offshore pipeline connecting onshore industrial emitter(s) to an existing offshore platform, as well as modifications to existing storage infrastructure. This project is estimated to cost €160m and could be operational as early as 2021 (subject to final investment decision in 2019).

- Phase 2: Other industrial emitters in Rotterdam could join the cluster in the second phase and potentially utilise the CO2 infrastructure. The capital cost of increasing the capture rate to 3 million tonnes of CO2 per annum, installation of onshore feeder pipelines, further modifications to existing storage infrastructure, and appraisal of further gas fields for cluster expansion is estimated to be €270 million in total but would require securing €60m for pre-FID activities including appraisal by 2019. The Phase 2 project could be operational by 2025/2026, and could be part-funded by the EU.

- Phase 3: Beyond Phase 1 & 2, the cluster would have the potential of expanding even further by including other emitters in Port of Rotterdam and rest of Netherlands, and enabling the deployment of other nearby industrial clusters including La Havre, Antwerp, Hamburg and Ruhr.

**3. European CCS clusters can be unlocked with grants, subsidies and guarantees**

Enabling the deployment of strategically important industrial CCS clusters in Europe will require a variety of coordinated funds and subsidies including grants for storage appraisal and construction; loan guarantees to unlock private investment; operational subsidies; and operational guarantees and sharing storage liability to de-risk the cluster. Key requirements of a typical industrial CCS project vary for the pre-FID (pre-Final Investment Decision), Construction, Operation and Post-closure phases.

Rotterdam is expected to be one of the first industrial CCS clusters in Europe and can be developed in phases. The region hosts one of the largest industrial clusters in Europe, and has access to the P18-4 gas field, which is already appraised and permitted. Although the partners developing the coal capture part of the ROAD project have withdrawn in June 2017, storing existing CO2 from the Port of Rotterdam in P18-4 field by investing in transport and storage infrastructure could present a short-term and possibly low-cost opportunity for the area. The project could re-use some existing oil and gas facilities and the right-sized CO2 infrastructure could enable the expansion of the cluster in further phases.
Accessing the Structural Funds post 2020 will be important to secure the required funding for several industrial CCS clusters by 2030. However, these are not currently available for deployment of industrial CCS clusters, as investment to achieve the reduction of GHG emissions from activities included in the ETS Directive is not supported.

Although Horizon 2020 may provide some limited funding for storage appraisal in the short-term, no EU fund or MS funding are available today to support the significant level of storage appraisal activity needed to unlock gigatonnes of bankable storage capacity over the next decades and H2020 does not typically provide the level funding needed for the appraisal of one aquifer (e.g. €50-100m).

If Project of Common Interest (PCI) status is achieved and Connecting Europe Facility funding application is successful, CEF Energy could potentially part-fund the CO2 pipeline(s) of the Rotterdam industrial CCS cluster; however, it should be noted that the Rotterdam PCI application included a cross-border CO2 infrastructure, which would be relevant for Phase 3 of this project.

Private investment can be leveraged for the construction phase with the right incentives and guarantees; however, it should be noted that equity and debt raised for the construction phase, and associated returns should be paid back during the operation phase of the project.

EU ETS related revenues can only be included in the project cash-flow if the carbon price is accompanied with government guarantees/subsidies. Total value of avoided CO2 emissions could be €1bn for the potential Rotterdam CCS cluster until 2035 depending on the EU ETS price. The guarantee of the EU ETS price will be key given that the price is highly uncertain and EU ETS is unlikely to be a key driver for the deployment of industrial CCS clusters.

The EU ETS Innovation Fund (IF) could provide up to 60% of the relevant costs of industrial CCS clusters after 2021 (or potentially earlier). Yet, the budget of the IF depends on the auction price of the emissions allowances and a decision on the funding allocation criteria has yet to be made by the end of 2017 in order to assess whether the IF is a likely source of funding for industrial CCS. However, even if available, the Innovation Fund is unlikely to be sufficient to deliver several industrial CCS clusters by 2030.
6. With government support, European industrial CCS clusters could be fully funded

Relevant Member States are expected to fill the remaining funding gap after EU ETS, private investment and EU funding options given the strategic importance of industrial CCS clusters. To enable the deployment of an industrial CCS cluster in Rotterdam, the Dutch government may need to provide the following: grant to fill the funding gap until 2020 (€220m); operational subsidies (€50m per annum on average); and risk mitigation instruments (including loan guarantees to unlock loans, operational guarantees to de-link the transport and storage from industrial emitters, and sharing storage liability to make the project bankable).

- Potential Member State support can be part-funded by EU allowance auctions and Structural Funds.¹
- Some of the funds that have been awarded to the ROAD project may be reused for an industrial CCS cluster in Rotterdam (i.e. €150m by the Dutch government, €180m from the EEPR, €60m from Horizon2020 and other Member States including Germany and Norway).
- Potential Horizon 2020 calls on storage appraisal, Connecting Europe Facility funding for CO₂ pipelines and other international funds (e.g. OGCI Climate Investments) could also reduce the overall Member State support required.

8. It may be possible to fund CCS through the European Regional Development Fund as a Research, Technological Development and Innovation activity, provided that CCS projects are included in the research and innovation strategies for smart specialization.

7. Recommendations to kick-start an industrial CCS cluster in Rotterdam

<table>
<thead>
<tr>
<th>2017</th>
<th>2021</th>
<th>2026 Operation</th>
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<td>Including storage appraisal</td>
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<tr>
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<tr>
<td>Phase 2 operational</td>
<td>Further appraisal for cluster expansion</td>
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1. SET UP FUNDS TO KICK-START AN INDUSTRIAL CCS CLUSTER

Key stakeholder: Dutch government
Deadline: 2017/18
It is vital that eligible and election criteria of Innovation Fund allow several industrial CCS clusters to have access to IF (e.g. €600m - €1bn per cluster), and that a separate funding mechanism is created for storage exploration and appraisal.

2. CREATE A CLUSTER REPRESENTATIVE TO SECURE FUNDING

Key stakeholder: Rotterdam cluster
Deadline: 2019/20
A single party representing the cluster is likely to be needed for coordinating the cluster activities, securing finance, making funding applications, etc. An existing Special Purpose Vehicle (SPV) can be developed by the regional stakeholders or an existing SPV such as ROAD can be assigned to deliver an Industrial CCS cluster in Rotterdam.

3. SET UP SUPPORT MECHANISM FOR INDUSTRIAL CCS

Key stakeholder: Dutch government
Deadline: 2019/20
Expansion of the industrial CCS cluster in Rotterdam will require operational subsidies (i.e. to the existing operating grant), Stimulation of Sustainable Energy Production - Stimulation of Energy Efficiency (DEE) and Innovation Fund. A regulator should be responsible for government, operational guarantees and storage liability sharing to de-risk the cluster, and operational guarantees and storage liability sharing to de-risk the cluster.

4. PROVIDE SUFFICIENT FUNDS TO INDUSTRIAL CCS CLUSTERS

Key stakeholder: European Commission
Deadline: 2020/21
It is vital that eligible and election criteria of Innovation Fund allow several industrial CCS clusters to have access to IF (e.g. €600m - €1bn for each cluster), and that a separate funding mechanism is created for storage exploration and appraisal.

5. RAISE FUNDS TO EXPAND INDUSTRIAL CCS CLUSTER

Key stakeholder: Rotterdam cluster
Deadline: 2017/18
The cluster should define a business model for the expansion (including standardised contracts for joining the cluster, T&F fees, etc.) based on the support mechanisms designed by the Dutch government, and apply for EU funds, government support and project finance to secure all funds, finance, guarantees and subsidies needed to expand the cluster.

6. CREATE FUNDS FOR FURTHER STORAGE APPRAISAL

Key stakeholder: European Commission
Deadline: as soon as possible
Although Horizon 2020 may provide some limited funding for storage appraisal in the short term, meeting long-term decarbonisation targets in Europe will require significant level of storage appraisal to unlock gigatons of bankable storage capacity. It is suggested that a separate funding mechanism is created for storage exploration and appraisal.

1 It may be possible to fund CCS through the European Regional Development Fund as a Research, Technological Development and Innovation activity, provided that CCS projects are included in the research and innovation strategies for smart specialization.
1. INTRODUCTION

1.1 The need for industrial CCS to achieve the Paris Agreement objectives

Carbon Capture and Storage (CCS) has been recognised, both internationally\(^5\), and in the EU, as a key technology in reducing CO\(_2\) emissions in the energy-intensive manufacturing industry, which will become vital for meeting long-term greenhouse gas reduction targets. CCS is also key to Europe’s Energy Union Strategy as 330,000 jobs could be created and secured in fuel supply, CCS equipment manufacture, plant operation and CO\(_2\) storage facility operation\(^6\). CCS infrastructure is also important to retain the existing energy-intensive industries, which currently employ more than 1 million people in Europe, by mitigating the long-term carbon price risk.

The whole energy system modelling of 10 European countries, carried out by ZEP recently\(^7\), showed that:

- The value CCS to the EU could be in excess of €1 trillion by 2050 alone and in the longer term, and as European countries move towards net zero emissions, the value of CCS is expected to further increase to more than €50 billion per annum.
- The future of energy intensive industries including cement, steel and oil and gas is highly dependent on CCS. For these sectors and many more, CCS is critical to retaining high-skilled jobs and boosting economic activity across EU Member States in an increasingly carbon-constrained world.
- Infrastructure investments are needed now to achieve the lowest emissions and lowest costs out to 2050. CCS infrastructure can unlock emissions reductions across the whole energy system with significant potential for cost reductions through cross-border initiatives and sharing of infrastructure.

Development of industrial CCS projects as “clusters” offers significant deliverability and commercial advantages by achieving economies of scale – compared to the isolated and commercially challenging point-to-point projects. Similar to the natural gas pipelines, CO\(_2\) transport and storage infrastructure benefits from economies of scale (e.g. building one large trunk pipeline is more cost effective than building several smaller pipelines). Also, large emission sources such as industrial emitters often historically grew close to each (e.g. near ports or rivers), which leads logically to the development of CO\(_2\) capture clusters and shared transport and storage infrastructure. Shared infrastructure within industrial clusters can reduce cost and risk for multiple industrial emitters\(^8\).

The “Executable Plan for CCS in Europe”\(^9\) illustrates how commercial CCS deployment needs to evolve through a number of phases.

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\(^6\) Zero Emissions Platform (ZEP) modelling Source: ZEP, 2015, A 5 Point Action Plan

\(^7\) Zero Emissions Platform (ZEP), 2017, CCS and Europe’s Contribution to the Paris Agreement

\(^8\) Zero Emissions Platform (ZEP), 2016, Identifying and Developing European CCS Hubs

\(^9\) Source: ZEP including Element Energy, 2015, An Executable Plan for enabling CCS in Europe
1.2 Purpose of this study and Methodology

Element Energy and i2-4c have sought to develop a funding pathway combining existing and future European funds and other financing instruments to leverage private investment and successfully deliver at least one industrial CCS cluster in Europe. Over a period of six months and with significant input from European CCS stakeholders, the project has assessed the key requirements of a potential industrial CCS cluster in Rotterdam, and developed a funding pathway for the cluster with specific actions for various stakeholders.

- Section 2 presents the key requirements of industrial CCS clusters.
- Section 3 discusses how a potential industrial CCS cluster in Rotterdam can be developed in phases.
- Section 4 reviews potential private and public funding/financing options, which can be applied to other (industrial) CCS clusters.
- Section 5 presents the funding pathway and the key recommendations for the European Commission, Member States and project developers.

**Figure 1: Phased development of a CCS cluster**

**Phase 1**
Deliver existing single source/sink CCS demonstration projects in prime locations which can be expanded into strategic European CO₂ hubs.

**Phase 2**
Start sourcing CO₂ from nearby emitters to create CCS hubs, i.e. clustering additional CCS projects near the ground breaking CO₂ infrastructure. Ensure that the storage capacity identified, usually distributed over several depleted oil/gas fields or deep saline formations, is appraised well in advance of its need, driven by hub expansion.

**Phase 3**
Expand the hub over a wider region and potentially across neighbouring countries.

*This diagram was adapted from: ZEP report “Executable Plan for CCS in Europe”*
2. REQUIREMENTS OF AN INDUSTRIAL CCS CLUSTER

Key requirements of a typical industrial CCS project vary for the pre-FID, Construction, Operation and Post-closure phases. Although each cluster in Europe might have specific challenges and requirements, some generic requirements apply to most prospective projects. In order to address these requirements and support the project throughout its lifetime, a variety of financial support mechanisms is required, including grants, debt, operational subsidies, and guarantees. These requirements are explained below for each phase.

Figure 2: Requirements for different phases of industrial CCS cluster development

<table>
<thead>
<tr>
<th>Phase</th>
<th>Grants for storage appraisal, feasibility studies and front-end engineering design</th>
<th>Debt from e.g. banks, EIB</th>
<th>Loan guarantees for parties with credit rating below investment grade</th>
<th>Grants, required if equity and debt insufficient to cover all costs</th>
<th>Sufficient revenues in the operation phase to cover decommissioning costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-FID (3-10 yrs)</td>
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<tr>
<td>Construction (3-5 yrs)</td>
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<td>Operation (10-40 yrs)</td>
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<tr>
<td>Post-Closure (20+ yrs)</td>
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2.1 Pre-FID phase

- This phase includes all of the activities required before the project can take a Final Investment Decision and might take between 3 and 10 years. The key factor that has an impact on the duration of this phase is whether the cluster already has proven storage capacity. If not, storage assessment and exploration and appraisal activities might take more than 5 years (e.g. for a new aquifer).
- In addition to storage assessment and appraisal, feasibility studies and Front End Engineering Design including the assessment of suitability of existing assets should be carried out for all industrial emitters, and transport and storage infrastructure.
- CCS is a proven technology but it is not commercial yet, so grants are still vital for pre-FID activities – especially for storage assessment and appraisal.
- Although the cost of pre-FID activities are likely to be significantly lower than the Construction and Operational phases, all of the funds, subsidies, guarantees, business model, regulatory framework (e.g. for storage permitting, long-term storage liability, etc.) and contractual arrangements for the future phases should be defined in this phase so that the project partners can take the FID.

* Final Investment Decision
2.2 Construction phase

- This is a capital-intensive phase so a combination of equity/debt and grants might be needed. Depending on balance sheet capacity, equity could be obtained from industrial shareholders or 3rd party sponsors. However, high cost of equity (target return on equity of 10%-15%) means that, for each €1 of equity invested, €2 of public funds might be needed.
- Loans and other debt instruments from the European Investment Bank & commercial banks might also be available for industrial CCS projects; however, loan guarantees are likely to be required for first-of-a-kind CCS projects and for parties with credit rating below investment grade.
- Grants are important for this phase, especially for first-of-a-kind projects. Grants can also lower the overall project cost – this will be explained in more detail in Section 3.

2.3 Operation phase

- The main revenue source for the cluster in this phase is expected to be government subsidies and EU ETS emissions allowances.
- The project-on-project or cross-chain risks should also be mitigated via government guarantees that might include storage guarantees to emitters and volume guarantees to transport and storage operator(s).
- It should be noted that the operation phase includes both the injection and post-injection monitoring activities, which does not generate any CO₂ related revenues but has a cost to the CO₂ storage operator before it is entitled to hand over to government for post closure.

2.4 Post-closure phase

- This phase includes the decommissioning and monitoring liabilities of project developers.
- Long-term storage liability as defined in the European CCS Directive is a key challenge for private storage operators and sharing storage liability might be needed. The storage liability sharing is included in this phase but it is expected that liability will need to be shared with the MS during the operation phase as well.
- Similarly, decommissioning costs can be significant, especially for offshore transport and storage infrastructure, so sufficient revenues during the operation phase are required to cover decommissioning costs.

Achieving coordinated pre-FID, construction and operation activities across CO₂ capture, transport and storage is a complex task that may be simplified via the establishment of a single project entity in charge of coordinating the CCS cluster project activities. For instance, Teesside Collective was formed to represent a cluster of multi-national companies working together to establish Teesside in Tees Valley as one of Europe’s most attractive locations for future clean industrial development. Project partners may create a Special Purpose Vehicle (SPV) for engaging with government, European Commission and banks; or a Market Maker can be established and funded by the government.

The next section explains the specific requirements of an industrial CCS cluster in Rotterdam over time.

11 http://www.teessidecollective.co.uk/welcome/partners/
3. DEVELOPMENT OF AN INDUSTRIAL CCS CLUSTER IN ROTTERDAM

3.1 Potential phased development of an industrial CCS cluster in Rotterdam

The lessons learned of scaling a CCS cluster in Rotterdam, could be key in further transport and storage infrastructure roll-out in Europe. Although the partners developing the coal capture part of the Rotterdam Capture and Storage Demonstration Project (ROAD), which was intending to capture CO₂ from a coal plant and store in a depleted gas reservoir under the North Sea, have withdrawn, Rotterdam is still expected to be one of the first-mover CCS clusters in Europe as:

- Rotterdam has plenty of depleted or near depleted gas fields and aquifers which could offer CO₂ storage potential, some of which is already fully appraised and permitted.
- The area also hosts one of the largest industrial clusters in Europe within a relatively dense area; and
- Rotterdam is expected to be an enabler for a wider CCS network in the future, linking the industrial clusters of Antwerp, Ruhr, North Rhine-Westphalia, Le Havre, etc.

Recent statement from the Port of Rotterdam confirms that Rotterdam will continue to explore alternative options to develop a CCS cluster.

“Both internationally and in the Netherlands national Energy Agenda, CCS is viewed as an important instrument for cutting back the volume of CO₂ released into the atmosphere. At present, petroleum refineries and the chemical industry are two sectors faced with a particular shortage of renewable or circular alternatives. The capture and storage of CO₂ presents these sectors, which are important both in economic and social terms, with opportunities to reduce their CO₂ emissions.

That is why the Port of Rotterdam Authority and a number of other parties are jointly examining which options they have to realise a basic infrastructure in Rotterdam’s port areas for the collection and transport of CO₂ and its subsequent storage in (empty) gas fields in the North Sea seabed. Realising this loop pipeline (or ‘backbone’) and the associated storage infrastructure as a ‘collective facility’ will create significant economies of scale.”

Potential CO₂ storage at the P15 and P18 gas fields presents a closing window of opportunity for Rotterdam, unless a business case is made soon for the transformation of currently active gas fields within P15 and P18 to CO₂ storage sites, these will need to be mothballed in the early 2020s – thus adding cost to the project – or decommissioned. The Port of Rotterdam area has an existing system which delivers CO₂ from the industrial emitters to greenhouses and the surplus CO₂ is currently being emitted. Storing this “excess” 0.5 Mt of CO₂ per annum (as stated in the draft SET Plan) in P18-4 field, which is already appraised and permitted, by investing in transport and storage infrastructure (including re-using some existing O&G facilities) would present a short-term and relatively low-cost opportunity for the area, which can enable the expansion of the cluster in the following phases. We have therefore developed this hypothetical initial phase, called “Phase 1” in our analysis (Figure 3).

Cost estimates for pre-FID, construction and operational phases are shown below (Table 1 and Figure 4). These are only illustrative at this stage, although they have been validated by a number of expert stakeholders. Actual costs and funding requirements might be different due to cost uncertainty and contingencies.

The second phase is the expansion of this cluster from ~0.5 Mt to ~3 Mt per annum by investing in new capture facilities, which can utilise the pipelines installed in the first phase. Further storage appraisal and modifications to existing storage infrastructure are also needed in this phase.

Phase 3 would include expansion of this cluster even further by including other emitters in Port of Rotterdam and the rest of the Netherlands, and potential connections with other nearby industrial clusters including La Havre, Antwerp and Ruhr. This phase would also include new transport and storage infrastructure including development of other nearby aquifers including a pipeline between Antwerp and Rotterdam utilizing existing pipeline corridors, CO₂ shipping connecting Le Havre and Hamburg, and inland shipping of CO₂ on the Rhine. It should be noted that this project focuses on Phase 1 and Phase 2, and further expansion of the Rotterdam cluster in Phase 3 is not in scope.

Development of a potential industrial CCS cluster in Rotterdam in a number of phases is illustrated in Figure 3 below.

Figure 3: Development of an industrial CCS cluster in Rotterdam in phases (illustrative)

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13 Ros et al., 2014. Start of a CO₂ hub in Rotterdam: connecting CCS and CCU
14 ZEP, ongoing. SETPLAN TWiG CCS and CCU Implementation Plan
16 Capture cost estimates are based on an extensive modelling study carried out by Element Energy in the UK. Element energy et al. for DECC and BIS, 2014, Demonstrating CO₂ capture in the UK
17 Transport and storage costs are based on the discussions with the regional stakeholders and final estimates used are consistent with the costs included in the Draft SET Plan. A number of CCS project developers and regional stakeholders have reviewed and endorsed the figures used in the assessment.
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Table 1: Phase 1 costs for capture, transport and storage

<table>
<thead>
<tr>
<th>Notes</th>
<th>Pre-FID</th>
<th>Constr.</th>
<th>Ops.</th>
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<td>• Existing “excess” 0.5 Mt of CO₂ is captured per annum as stated in the draft SET Plan</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>• This phase does not require any capital investment in capture facilities</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Transport</td>
<td>• Offshore backbone pipeline and offshore pipeline connecting potential onshore industrial emitters(s) to P18-A platform, which can be used for Phases 1 and 2</td>
<td>€5m</td>
<td>€115m per annum</td>
</tr>
<tr>
<td></td>
<td>• Further appraisal is not required for this phase as P18-A is already permitted but some budget is included for pre-FID to assess and review integrity of existing O&amp;M facilities</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Storage</td>
<td>• Modifications to P18-A platform and P18-4 field well are included</td>
<td>€5m</td>
<td>€35m</td>
</tr>
</tbody>
</table>

Table 2: Phase 2 costs for capture, transport and storage

<table>
<thead>
<tr>
<th>Notes</th>
<th>Pre-FID</th>
<th>Constr.</th>
<th>Ops.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture</td>
<td>• Total capture rate is increased to 3 Mt/yr (in total) from industrial emitters in Rotterdam including Refining (0.5 Mt), Chemicals (1 Mt), Bio-ethanol (0.5 Mt) and Hydrogen (0.5 Mt)</td>
<td>€20m</td>
<td>€570m</td>
</tr>
<tr>
<td></td>
<td>• Offshore and offshore pipelines installed in Phase 1 can be used in this Phase</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Transport</td>
<td>• Only small investment in onshore feeder pipelines are required for new emitters and additional compression costs are included in the capture costs</td>
<td>€120m per annum</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>• Appraisal of P18 and P15 gas fields (and potentially nearby Lower Cretaceous aquifers) for cluster expansion</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Storage</td>
<td>• Further modifications to P18-2 field wells and P18-A platform assuming the gas wells can be re-used for CO₂ injection</td>
<td>€40m</td>
<td>€40m</td>
</tr>
</tbody>
</table>

The described project would store more than 30 million tonnes of CO₂ by 2035. Levelised cost of abatement of this cluster (Phases 1 and 2 combined) is estimated to be ~€70/tCO₂ if Phase 2 project stays operational only for 10 years. Increasing the lifetime of this project until 2045 (assuming existing storage infrastructure has enough design life) would double CO₂ storage and abatement, and reduce the levelised cost of abatement to ~€50/tCO₂.

As the CO₂ storage site that will be used for the first phase has already been appraised and permitted, the Phase 1 project could be operational by 2021 and enable development of further phases. Working backwards, the project should take final investment decision in 2019 and the project developer(s) should secure ~€160 million of grant for the pre-FID and construction phases by next year, which is the key challenge for this initial phase.

Based on the illustrative timeline, the Phase 2 project (i.e. cluster expansion) should secure €60m for pre-FID activities including appraisal of P18 and P15 gas fields by 2019. Construction funds, operational revenues, subsidies and guarantees should be identified and allocated by 2023 so that the project can take final investment decision. The Phase 2 project could be operational by 2025/2026, and could be part-funded by the EU, as it is expected that further EU funding will be available post 2021. This will be explored in more detail in the next chapter.

18 Discounted lifetime costs of the project divided by discounted lifetime CO₂ abatement – which is lower than CO₂ storage due to the additional emissions associated with CCS operations.
Although the cluster has some challenging funding requirements, a variety of public and private funding options might be made available to this potential cluster, which is expected to enable the deployment of other industrial CCS projects in Port of Rotterdam and rest of Netherlands, and other nearby industrial clusters including La Havre, Antwerp and Ruhr. These funding options are explored in the next chapter.

### Illustrative timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>Final investment decision</td>
</tr>
<tr>
<td>2022</td>
<td>Construction work</td>
</tr>
<tr>
<td>2023</td>
<td>Phase 2 is operational (3 Mt/yr)</td>
</tr>
</tbody>
</table>

**Phase 1**
- Secure 100% grant (£160 million) for the pilot project
- Final investment decision
- Construction (backbone onshore pipeline; offshore pipeline; mods to P-18-A and P18-4 field)
- Pilot project is operational (0.5 Mt/yr)

**Phase 2**
- Secure £60 million for appraisal of P18 and P15, and other pre-FID work for cluster expansion
- Final investment decision
- Construction work
- Phase 2 is operational (3 Mt/yr)
4. FUNDING PATHWAY

Enabling the deployment of Europe’s first-of-a-kind industrial CCS clusters will require a combination of different funding options, which are explored in this section. Broadly, we have identified four distinct options, including:

- EU emissions trading scheme (EU ETS)
- Private investment (i.e., equity and/or debt)
- EU funding options
- Member State and other funding options

4.1 EU Emissions Trading Scheme

The EU emissions trading scheme (EU ETS) was introduced to tackle climate change; however, the scheme has failed to reflect the real value of carbon reduction, and, as of 2017, EU ETS price is around €5/tCO₂. Emission allowances are normally allocated to the participating companies via auctioning; however, some of the industrial emitters receive free allowances as they are exposed to a “carbon leakage” risk. As some of the industrial products such as iron and steel are traded internationally, it is not possible for industrial manufacturers to pass the increasing cost of carbon onto their consumers. If they do not receive free allowances, carbon leakage may occur — i.e. they may transfer their facilities to other countries with lower carbon prices19.

As the EU ETS price is also highly uncertain, potential EU ETS-related revenues cannot make a CCS project investable. EU ETS is therefore unlikely to be a key driver for the deployment of industrial CCS clusters in Europe. However, EU ETS-related revenues can be included in the project cash-flow if the carbon price is accompanied with government guarantees/subsidies. Government subsidies such as contract-for-difference or a “minimum price guarantee” would provide the required certainty to private investors. Through this subsidy mechanism, the cluster or emitter could receive the difference between an agreed minimum CO₂ price and EU ETS price. Alternatively, if the European Commission continues to provide free allowances beyond 2020, emitters could return their free allowances to the Member State and receive the full payment — this would have a similar impact on the project cash-flow and the policy cost.

The cash-flows below show the project costs and potential EU ETS-related revenues (in green) assuming all industrial emitters in the cluster will be included in EU ETS throughout the project lifetime. Total value of avoided CO₂ emissions could be €11bn until 2035 and more than €2.5bn until 2045; however, these potential revenues should be accompanied by government guarantees. A funding gap exists until the late 2030s based on the EU ETS price forecast used (EU 2016 Reference Scenario20, updated to 2017 values), which increases to €20/CO₂ in the early 2020s and €40/CO₂ in the early 2030s. The funding gap after EU ETS is €160m for the first phase and €1.2 billion for the whole project (phases 1 and 2 combined). If the funding gap can be filled with a combination of other funding and financing options, the project might be self-sustaining in the late 2030s but it should be noted that EU ETS price is highly uncertain; the funding gap might be significantly higher if the EU ETS price does not increase in the 2020s and 2030s as expected.

19 It is stated in the EU ETS Handbook that “Any sector that it is deemed to face a significant risk of carbon leakage from exposure to non-EU competition due to price on CO₂ will continue to receive up to 100% of the quantity determined by the free allocation rates for free throughout the entirety of phase 3” Available at: https://ec.europa.eu/clima/sites/clima/files/docs/ets_handbook_en.pdf

20 European Commission, 2016, EU Reference Scenario

4.2 Private investment

Leveraging private investment is an important aspect of the European Commission’s Energy Union goal. This was also reiterated by Commissioner Cañete21: “We need to leverage private investments through public support, in particular when it comes to building interconnections and infrastructure, energy efficiency and renewable energy.” Private investment options for industrial CCS can be broadly categorised under the following two categories:

- Debt: Loans and other debt instruments from the European Investment Bank and commercial banks with long maturity (e.g. 10-year) and low-interest rate (e.g. 3%) might be available for bankable CCS projects. Most first-of-a-kind CCS projects are likely to require government loan guarantees to become bankable.

- Equity: Depending on balance sheet capacity, it could be obtained from industrial shareholders or third party sponsors; however, high cost of equity (target ROE of 10%-15%) means that, for each €1 invested, €2 of public funds might be needed.

Private investment can be leveraged with the right incentives and guarantees; however, both equity and debt should be paid back. Industrial emitters, for instance, might typically require very short payback period for their capital investment (e.g. 3-5 years); however, repayment length for debt might be 10 years depending on the guarantees in place. Private investors and equity providers would also require returns on investment depending on the risk profile of the project. In summary, the

21 Operational costs include an annual fee for funding of decommissioning plan similar to “Funded Decommissioning Programme” for nuclear

right guarantees can unlock private investment, but private investment shifts the funding gap from construction to operation. This is illustrated in the cash-flow below assuming 60% debt and 40% equity, and a repayment period of 10 years for both equity and debt. Capital grants can lower the required level of equity and therefore the funding gap during the operational phase of the project. Minimising equity returns would also reduce the overall cost of the project.

Figure 7: Potential impact of private investment on project cash-flow

4.3 European funds

European funding options for industrial CCS clusters are limited at present but important potential sources of funds are expected to become available in 2019-2021. A variety of European funds have been assessed and four relevant options for an industrial CCS cluster in Rotterdam have been identified. It should be noted that the EU is still developing the Multiannual Financial Framework post-2020.

In this context, additional funding modalities and different budget allocation between funds can be assessed and four relevant options for an industrial CCS cluster in Rotterdam have been identified. ERDF has a collective budget about €55bn (of which ~€4bn is allocated to financial instruments) by 2020. Overall budget depends on auction price of emission allowances – ranges between €2bn (€18bn assuming an average EUA price of €25).

Majority of the budget is expected to become available after 2021; however, some limited funds might become available earlier (e.g. remaining funds from the second call of the NER300 Programme). Expected to cover up to 60% of relevant costs and might include financing instruments and guarantees in addition to grants.

Table 3: Summary of relevant EU funding options

<table>
<thead>
<tr>
<th>Key Constraints</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eligibility and selection criteria have not been developed yet so it is uncertain how much funding can be allocated to industrial CCS clusters considering that the fund will also support renewable energy, CCU, energy storage and other innovative industrial technologies.</td>
<td>Aims to support “demonstration projects of innovative carbon capture, storage and use (CCS/CCU), energy storage and biocarbon innovation in energy intensive industry” and likely to have a technology-neutral approach.</td>
</tr>
<tr>
<td>It is unlikely to address the funding requirements of an industrial CCS cluster in Rotterdam before 2020. If funding is linked to verified CO2 storage (as was the case in NER300 funding mechanism), getting upfront funding/grant (that may need to be paid back if the project does not go ahead) is unlikely to be an attractive option for industrial CCS project developers.</td>
<td>Investment to achieve the reduction of GHG emissions from activities listed in Annex I to the ETS Directive is supported, hence commercial CCS activities are excluded. As an exception to the above, CCS activities fall within scope if they are for research, development and testing of new products and processes.</td>
</tr>
</tbody>
</table>

Eligibility and selection criteria have not been developed yet so it is uncertain how much funding can be allocated to industrial CCS clusters considering that the fund will also support renewable energy, CCU, energy storage and other innovative industrial technologies. It is unlikely to address the funding requirements of an industrial CCS cluster in Rotterdam before 2020. If funding is linked to verified CO2 storage (as was the case in NER300 funding mechanism), getting upfront funding/grant (that may need to be paid back if the project does not go ahead) is unlikely to be an attractive option for industrial CCS project developers.

European Regional Development Fund (ERDF) is the most relevant fund for an industrial CCS cluster in Rotterdam. Additionally, the Cohesion Fund may be relevant for other industrial CCS clusters as it is aimed at Member States whose GNI per inhabitant is less than 90% of the EU average. ERDF has a collective budget about €55bn (of which ~€4bn is allocated to financial instruments) by 2020. Future of Structural funds post 2020 is linked to Multiannual Financial Framework (MFF) review.

Majority of the budget is expected to become available after 2021; however, some limited funds might become available earlier (e.g. remaining funds from the second call of the NER300 Programme). Expected to cover up to 60% of relevant costs and might include financing instruments and guarantees in addition to grants.

European Investment Bank offers loans and other debt instruments to projects with demonstrated bankability so they are not examined here separately. EIB loans and potential public equity options can replace private equity and loans, which were explained in the “Private investment” section.


More detailed information is available at: [http://ner400.com/](http://ner400.com/)

More detailed information is available at: [http://ec.europa.eu/energy/en/funding](http://ec.europa.eu/energy/en/funding)
As explained in the table above, Innovation Fund can provide ~60% (or more, depending on the final text of the ETS Reform) of the relevant costs of a potential industrial CCS cluster in Rotterdam after 2021 (or potentially earlier) but the budget depends on the auction price of the emissions allowances and carved out budget for industrial CCS projects might be limited as a technology neutral approach is likely to be implemented. Potential contribution of Innovation Fund also depends on how “relevant costs” are defined for the operational costs. For instance, assuming 60% of Phase 2 construction costs are covered by Innovation Fund (~€400m) and remaining 40% is funded by a combination of equity (10%) and loan (30%), total annual cost in the Operational phase would be €170m/year including ~€135m of operational expenditure and ~€35m for equity return and loan repayment. In 2026, EU ETS-related revenue (i.e. value of free allowances or avoided allowance cost) is estimated to be ~€75m. Depending on how financial costs and potential EU ETS related revenues are treated in the definition of “relevant costs,” Innovation Fund contribution in 2026 could vary between €36m and €95m as illustrated in the table below.

Another limiting factor for the Innovation Fund is the potential impact of EU ETS price both on the total budget of IF and funding requirement of an industrial CCS cluster in Rotterdam. Under a conservative assumption that “relevant costs” do not include financial costs and net of ETS related revenues, total funding requirement for an industrial CCS cluster would be more than €600m until 2035 (i.e. ~€400m for capital expenditure and ~€200m for relevant operational costs until 2035). Potential contribution of Innovation Fund might increase significantly if the EU ETS price does not increase as expected in the 2020s and 2030s. For instance, using a low EU ETS price of €8/tCO2 for the period until 2035, contribution required from Innovation Fund would increase to more than €1 billion for the industrial CCS cluster. On the other hand, due to the low EU ETS prices, total IF budget would go down to only €3bn12.

Figure 8: Impact of EU ETS price on Innovation Fund contribution

### Table 4: Impact of the definition of “relevant costs” on Innovation Fund contribution

<table>
<thead>
<tr>
<th>Category</th>
<th>Excluding financial costs and net of ETS related revenue</th>
<th>Including financial costs but net of ETS related revenue</th>
<th>All annual costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF contribution to this project</td>
<td>€0.6bn</td>
<td>€0.95bn</td>
<td>€1.70bn</td>
</tr>
<tr>
<td>Pre-FID work</td>
<td>-€300m</td>
<td>-€200m</td>
<td>-€100m</td>
</tr>
<tr>
<td>ETS related revenue</td>
<td>-€59m</td>
<td>-€38m</td>
<td>-€0m</td>
</tr>
<tr>
<td>Funding Gap</td>
<td>-€300m</td>
<td>-€200m</td>
<td>-€100m</td>
</tr>
<tr>
<td>Avoided emissions cost</td>
<td>-€1bn</td>
<td>-€1bn</td>
<td>-€1bn</td>
</tr>
<tr>
<td>Equity (&amp; returns)</td>
<td>-€75m</td>
<td>-€75m</td>
<td>-€75m</td>
</tr>
<tr>
<td>Debt (&amp; repayment)</td>
<td>-€170m</td>
<td>-€170m</td>
<td>-€170m</td>
</tr>
<tr>
<td>Innovation Fund</td>
<td>-€1bn</td>
<td>-€1bn</td>
<td>-€1bn</td>
</tr>
<tr>
<td>Capital expenditure</td>
<td>-€600m</td>
<td>-€600m</td>
<td>-€600m</td>
</tr>
</tbody>
</table>

12 Sandbag, 2015, Consultation Response Revision of the EU ETS Directive
In other words, potential contribution of Innovation Fund to only one industrial CCS cluster project described in this report may correspond to one-third of the total IF budget. It is therefore vital that Structural Funds are made available to industrial CCS projects post 2020 to deliver the strategically important industrial CCS cluster in Europe in the 2020s. Structural Funds can also be used by the Member States to fill the remaining funding gap after the Innovation Fund.13

In summary, European funding opportunities including Innovation Fund and Structural Funds may be available to support industrial CCS clusters in Europe; however, funding availability before 2020 is likely to be extremely limited.

As illustrated in the timeline below, European funds can be used to fund the construction and operation phases of the Phase 2 project; however, a funding gap exists for the Phase 1 project and the pre-FID activities of the Phase 2 project including storage appraisal. It should also be noted that the most relevant funding option for storage appraisal is currently Horizon2020, which does not typically provide the level funding needed for the appraisal of one aquifer (e.g. €50-100m for a new aquifer).

Figure 9: Timeline of potential EU funds compared to key project requirements

<table>
<thead>
<tr>
<th>PHASE 1</th>
<th>PHASE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secure €160m for Phase 1 project</td>
<td>Secure €40m for pre-FID work</td>
</tr>
<tr>
<td>Phase 1 operational costs</td>
<td>Phase 1 pre-FID</td>
</tr>
<tr>
<td>Phase 1 construction</td>
<td>Secure pre-FID work</td>
</tr>
<tr>
<td>Structural Funds</td>
<td>Secure storage funds (€660m)</td>
</tr>
<tr>
<td>other structural funds: Horizon 2020</td>
<td>Secure operational funds &amp; guarantees</td>
</tr>
<tr>
<td>EDF</td>
<td>Coordinate full-chain FID</td>
</tr>
<tr>
<td>Construction work</td>
<td>Operational costs</td>
</tr>
</tbody>
</table>

Member State and other funding options:

The remaining funding gap after EU ETS, private investment and EU funding options is expected to be filled by the relevant Member State considering the strategic importance of industrial CCS clusters. For an industrial CCS cluster in Rotterdam, the potential role of the Dutch government can be summarised as follows16:

- Providing grant to fill the funding gap until 2020: The current funding gap for the low-cost Phase 1 project is estimated to be €160m. In addition to this, €60m is needed for storage appraisal and pre-FID activities of Phase 2. The Dutch government could provide a grant to fill this funding gap. For instance, the ROAD project was awarded €150 million by the Dutch Government in 2010, which may not be needed for the power plant anymore due to the cancellation. Other ROAD funding may also be reused for this cluster including €180m from EEPR, and €60m from Horizon 2020 and other Member States. Other funding options such as H2020, CEF, OGCI, etc. would lower the amount of grant funding required; however, it is not certain how much funding (if any) can be made available from these other funding sources before 2020.

- Providing operational subsidies: As explained in the “EU ETS” section, EU ETS related revenues can be included in the cash-flow if they are accompanied by government subsidies. In this assessment, we assume a “minimum CO₂ price” incentive scheme similar to Contract-for-Difference subsidies (e.g. SDE+ in Netherlands) provided to the renewable energy projects – i.e. project developers agree a strike CO₂ price with the government and government provides the difference between the agreed strike price and the EU ETS price (net of any other EU funding such as Innovation Fund). Alternatively, if the European Commission continues to provide free allowances beyond 2020, emitters could return their free allowances to the Member State and receive the full payment.

- Risk sharing: The Dutch government can provide a variety of guarantees including loan guarantees to unlock loans, operational guarantees (such as volume and storage guarantees) to de-link the transport and storage from industrial emitters, and sharing storage liability to make the project bankable.

With support from Member State, the project could be fully funded as illustrated in the cash-flow below. Total MS support needed is estimated to be €220m before 2020 for pre-FID and construction, and €50/annum on average for the operational phase. It should be noted that potential Member State support can be part-funded by EUA auctions, since at least 50% of auctioning revenues are suggested to be used for climate and energy related purposes, and Structural Funds as explained above. Potential Horizon2020 calls on storage appraisal and CEF funding for CO₂ pipelines in the region could also reduce the overall Member State support required. Finally, other international funding options such as the Oil and Gas Climate Initiative’s $1 billion of investment that was announced in 201616 might also provide some grant funding or investment.

Figure 10: Cash-flow illustrating funding sources for Rotterdam industrial CCS cluster

Available at: http://www.oilandgasclimateinitiative.com/news/announcing-ogci-climate-investments
### Table 5: Split of funds until 2035 (€million)

<table>
<thead>
<tr>
<th>Million (undiscounted)</th>
<th>Phase 1 Pre-FID and Constr.</th>
<th>Phase 2 Pre-FID</th>
<th>Phase 2 Constr.</th>
<th>Ops.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon savings</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,070</td>
<td>1,070</td>
</tr>
<tr>
<td>Private Investment</td>
<td>0</td>
<td>0</td>
<td>260</td>
<td>0</td>
<td>260</td>
</tr>
<tr>
<td>EU via Innovation Fund</td>
<td>0</td>
<td>0</td>
<td>400</td>
<td>210</td>
<td>610</td>
</tr>
<tr>
<td>MS Contribution</td>
<td>160</td>
<td>60</td>
<td>0</td>
<td>490</td>
<td>710</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>160</strong></td>
<td><strong>60</strong></td>
<td><strong>660</strong></td>
<td><strong>1,770</strong></td>
<td><strong>2,650</strong></td>
</tr>
</tbody>
</table>
5. RECOMMENDATIONS AND KEY MESSAGES

Although the partners developing the coal capture part of the ROAD project have withdrawn, potential CO₂ storage at the nearby offshore gas fields might present a closing window of opportunity for Rotterdam to develop an industrial CCS cluster. The current European funding options are not sufficient to meet the short-term requirements of an industrial CCS cluster in Rotterdam; however, with potential support from the Dutch government, an industrial CCS cluster in Rotterdam can be kick-started. The cluster could then expand in the early 2020s by leveraging a combination of private and European funding.

The timeline below (Figure 11) illustrates the key actions for the Dutch government, Rotterdam cluster and the European Commission.

Figure 11: Illustrative action plan to deliver an industrial CCS cluster in Rotterdam

5.1 Member States (e.g. Dutch Government)

Action 1: Set up funds to kick-start an industrial CCS cluster in Rotterdam

Our assessment showed that ~€160 million might be sufficient to fund the low-cost Phase 1 project, which would allow storing the existing 0.5 Mt of CO₂ per annum from the Port of Rotterdam in P18-4 field (already appraised and permitted) by investing in transport and storage infrastructure. The pipelines in Phase 1 can be used by other industrial emitters that are expected to join the cluster in Phase 2; however, storage capacity of P18-4 is not sufficient for the cluster expansion. An additional funding of ~€60 million is therefore needed mainly for the appraisal of P1B and P15 gas fields (and potentially nearby Lower Cretaceous aquifers if more funding is available) and other pre-FID activities.

Due to the limited European funding options before 2020, the Dutch government would need to fill the funding gap in the short-term to kick-start a cluster in Rotterdam. This relatively limited initial upfront funding from the Dutch government would be sufficient for the Rotterdam cluster to make progress before 2020 and secure significant amount of private and European funding (i.e. ~€1 billion in total) in the 2020s. This potential industrial CCS cluster could decarbonise the Port of Rotterdam by storing more than 30 million tonnes of CO₂ by 2035 and could enable the decarbonisation of other industrial emitters in Rotterdam and Netherlands, and other nearby European industrial clusters.

It should be noted that any other private and/or European funding (e.g. H2020 funding for storage appraisal, CEF funding for CO₂ pipelines, OGCI funding, etc.) would reduce the short-term funding requirement; however, the development of this cluster should not be delayed to wait for these uncertain funding sources considering the urgent need for early CCS deployment in Europe.

Action 3: Set up a support mechanism for industrial CCS projects

Grant funding may be sufficient for the Phase 1 project; however, the expansion of the cluster will require a number of actions by the Dutch government including the following:

- **Operational subsidies**: EU ETS price is highly uncertain so it may not be possible for the project developers to include EU ETS related revenues in the project cash-flow unless they are accompanied with government guarantees/subsidies. Through this subsidy mechanism, the cluster or emitter could receive the difference between an agreed minimum CO₂ price and EU ETS price (similar to SDE+ in Netherlands). Alternatively, if the European Commission continues to provide free allowances beyond 2020, emitters could return their free allowances to the Member State and receive the full payment to cover their ongoing costs.

- **Loan guarantees**: Accessibility to finance is being impaired by the lack of coherent CCS policy support in Europe. Without visibility on how CCS fits into energy and industrial policy, it is unlikely that private investors will fund a project without government guarantees. If debt is required, it is likely that a loan guarantee will be needed for first-of-a-kind industrial CCS projects and for parties with credit rating below investment grade. For instance, the US Department of Energy plans to provide a loan guarantee to the Lake Charles CCS project.56

- **De-risking the cluster**: In order to address the key cross-chain or project-on-project risks of the CCS cluster, the transport and storage operations should be de-linked from industrial emitters by introducing a combination of government guarantees such as volume guarantee to the transport and storage operator(s) and storage guarantees to the industrial emitters. Long-term storage liability is likely to be a challenge for private storage operators so storage liability needs to be shared with the governments.

Potential Member State support can be part-funded by EUA auctions, since at least 50% of auctioning revenues are suggested to be used for climate and energy related purposes, and Structural Funds through the ERDF as a Research, Technological Development and Innovation (RTDI) activity, provided the relevant Member States include it in their research and innovation strategies for smart specialisation.

5.2 Rotterdam cluster

Action 2: Create a cluster representative to secure Dutch funding

A number of CCS initiatives exist in Rotterdam, including the ROAD project, GATEWAY project and other studies led by Port of Rotterdam. However, it is not clear which entity would represent the potential industrial CCS cluster. Achieving coordinated pre-FID, construction and operation activities across the CCS chain (as explained above) is a complex task that may be simplified via the establishment of a single project entity in charge of coordinating the CCS cluster project activities. For instance, Teesside Collective was formed in the UK to represent a CCS cluster in the Tees Valley. A regional or national Market Maker (i.e. regional CO₂ transport and storage infrastructure development organization) can be established and funded by the Dutch government. Alternatively, regional stakeholders may create a Special Purpose Vehicle (SPV) for engaging with government, European Commission and banks or an existing SPV such as ROAD can be assigned to deliver an industrial CCS cluster in Rotterdam.

56 Available at: https://energy.gov/articles/energy-department-offers-conditional-commitment-first-advanced-fossil-energy-loan-guarantees
Once established, the cluster representative should secure Dutch funding for the Phase 1 project and for the pre-FID activities of the Phase 2 project. The cluster could then make enough progress over the next couple of years to be able to access significant amounts of private and European funding in the 2020s.

**Action 5: Raise private and public funds to expand industrial CCS cluster**

For the expansion of the cluster in Phase 2, further private and European funds should be secured to cover €660 million of construction costs and all ongoing subsidies and guarantees should be in place. The cluster representative could coordinate the activities to apply for EU funds, negotiating with the Dutch government and raising project finance.

Having access to Dutch and European funds is not sufficient for several other industrial emitters to join the cluster in Phase 2. The cluster should also define an investable business model for other emitters based on the support mechanism designed by the Dutch government. Potential industrial emitters that may join the cluster in Phase 2 will require standardised contractual arrangements with the cluster, T&S operator (e.g. third-party access conditions, take-or-pay contracts, liabilities, etc.), Dutch government and potentially the European Commission.

### 5.3 European Commission

**Action 4: Provide sufficient funds to industrial CCS clusters in Europe**

Various European funding options can be made available to enable the deployment of strategically important industrial CCS clusters in Europe. Specific recommendations are included below:

**Innovation Fund**

- **Eligibility and selection criteria:** Ring-fencing a substantial part of Innovation Fund budget for industrial CCS might enable the deployment of several industrial CCS clusters in Europe; however, a technology-neutral approach is likely to be implemented by DG CLIMA. As ring-fencing may not be possible, eligibility and selection criteria should be designed to allow industrial CCS clusters/projects to have access to sufficient funds. It is suggested that a separate study is commissioned (by DG CLIMA or CCS stakeholders) to explore the likely impact of different eligibility and selection criteria options on the competition between industrial CCS projects and other eligible technologies including renewables, CCU and other industrial decarbonisation measures. Such a study should also examine the learnings from the NER300 programme.

- **Milestone-based funding:** Allowing milestone-based upfront funding (appraisal, pre-FID and construction) as well as working grants (OPEX) that match the typical project requirements are crucial; however, funds should not be linked to strict FID and financial closure deadlines.

- **Budget required:** An illustrative cluster in Rotterdam might require €600m - €1bn from Innovation Fund as capital and operational grants (assuming the Innovation Fund's budget cap for one project is more than €600m) so it is suggested that Innovation Fund support a limited number of projects with higher funding requirement.

- **Financing required:** The cluster described in this report requires a variety of incentives and financial instruments in addition to grants. Loan guarantees, risk-sharing instruments and revenue support can also be provided by the Innovation Fund (unless these are already provided by the Member States for industrial CCS clusters).

**Structural Funds**

- Innovation Fund budget will depend on the ETS auction revenues, and if the EU ETS price remains low, contribution of IP to only one industrial CCS cluster project may correspond to one-third of the total IF budget. Innovation Fund is unlikely to be sufficient to deliver several industrial CCS clusters by 2030 so it is important for these clusters to have access to the Structural Funds, which are not currently available for deployment of industrial CCS clusters. As an exception to the above, CCS activities fall within scope if they are for research, development and testing of new products and processes.

- Since the ESI funds could provide a large additional budget, adding an exception to the ESI Funds eligibility rules for industrial CCS projects could address regulatory constraints that exclude the support of activities listed in Annex I of the ETS directive (and consequently of highTRL CCS applications). This could be justifiable considering the funding still caused by the risk of carbon leakage.

- Member States could also use the Structural funds in part to provide the required subsidies and guarantees.

**Action 6: Create funds for further storage appraisal in Europe**

- Although Horizon 2020 may provide some limited funding for storage appraisal in the short-term, no EU fund is available today to support the significant level of storage appraisal activity needed to unlock gigatonnes of bankable storage capacity over the next decades. It is therefore suggested that a separate funding mechanism is created for storage exploration and appraisal activities in Europe.

- An initial funding of €40-50m now for storage appraisal would suffice for an industrial CCS cluster in Rotterdam to progress, which can be fully or partly funded by the Dutch government. Each industrial CCS cluster in Europe might require €50-100m initially depending on the size of the cluster.

### 5.4 Summary of key messages

Important messages for all European industrial CCS clusters and Members States were identified based on the assessment carried out for Rotterdam, as summarised below:

1. **Industrial CCS clusters**, which have significant cost advantages compared to the point-to-point projects, are key to **European industrial decarbonisation**. CCS infrastructure is also important to retain the existing industrial jobs in Europe.

2. Enabling the deployment of strategically important industrial CCS clusters in Europe will require a **variety of funds and subsidies** including grants for storage appraisal and construction; loan guarantees to unlock private investment; operational subsidies; and operational guarantees and sharing storage liability to de-risk the cluster.
3. **Storage assessment/appraisal is the first activity of any CCS project**, and is a precondition for further progress. First industrial CCS clusters in Europe, which have access to proven/bankable storage capacity, can be operational by the early 2020s. Although Horizon 2020 may provide some limited funding for storage appraisal in the short-term, no EU fund is available today to support the significant level of storage appraisal activity needed to unlock gigatonnes of bankable storage capacity over the next decades.

4. **Industrial CCS clusters can be developed in phases**: First, low-cost, short-term opportunities (such as re-using existing infrastructure and starting with low-cost CO₂ capture) near existing industrial clusters can be identified and funded to deliver the enabling T&S infrastructure. Other industrial emitters can then join the cluster in the second phase based on the business model and incentive mechanism defined for a given cluster and Member State.

5. Achieving coordinated pre-FID, construction and operation activities across CO₂ capture, transport and storage is a complex task, which may be simplified via the establishment of a single cluster entity (e.g. Market Maker or Special Purpose Vehicle) in charge of coordinating the CCS cluster activities.

6. European funding opportunities including Innovation Fund and Structural Funds may be available to support industrial CCS clusters in Europe; however, funding availability before 2020 is likely to be extremely limited. Member States will therefore need to provide grant to fill the funding gap until 2020, operational subsidies, and risk mitigation instruments including loan guarantees to unlock loans, operational guarantees to de-link the transport and storage from industrial emitters, and sharing storage liability to make the project bankable. Potential Member State support can be part-funded by EUA auctions and Structural Funds. Potential Horizon2020 calls on storage appraisal and CEF funding for CO₂ pipelines in the region could also reduce the overall Member State support required.
APPENDIX 1: EU FUNDING SOURCES

Figure 12: Relevant EU funds for an industrial CCS cluster in Rotterdam

- EU Funds
  - Funds in support of ETS
  - Innovation Fund
  - Modernisation Fund
  - EU Regional Development Fund (ERDF)
  - EU Social Fund (ESP)
  - Cohesion Fund (CF)
  - EU Agricultural Fund for Rural Development (EAFRD)
  - EU Maritime and Fisheries Fund (EMFF)
  - Unspent NER 300

- EU structural and Investment Funds (ESI)
  - Via EIB
  - EU Fund for Strategic Investments (EFSI)
  - InnovFin Energy Demo Projects (EDP)
  - Horizon 2020
  - Connecting Europe Facility (CEF)
  - Research Fund for Coal and Steel

- Other Funds
  - EU Funds
  - Innovation Fund
  - Modernisation Fund
  - EU Regional Development Fund (ERDF)
  - EU Social Fund (ESP)
  - Cohesion Fund (CF)
  - EU Agricultural Fund for Rural Development (EAFRD)
  - EU Maritime and Fisheries Fund (EMFF)
  - Unspent NER 300
European Investment Bank

Like other funds managed by EIB, these two offer loans or other debt instruments to projects with demonstrated bankability.

### What is available

<table>
<thead>
<tr>
<th>European Fund for Strategic Investments (EFSI)</th>
<th>InnovFin Energy Demo Projects (EDP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>€33.5B via a number of debt instruments</td>
<td>Up to €50m, or 50% of project costs, via a number of debt instruments</td>
</tr>
<tr>
<td>Set to be extended after the end of the current edition in 2020</td>
<td></td>
</tr>
</tbody>
</table>

### Aims and eligibility considerations

<table>
<thead>
<tr>
<th>European Fund for Strategic Investments (EFSI)</th>
<th>InnovFin Energy Demo Projects (EDP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects need to contribute to EU objectives, e.g. sustainable growth and employment.</td>
<td>To de-risk investments in projects that demonstrate first-time commercial viability</td>
</tr>
<tr>
<td>Projects need to be mature enough to be bankable</td>
<td>Project should have high replicability and with prospects of long-term cost efficiency</td>
</tr>
<tr>
<td></td>
<td>Project required to become bankable in 4 years, and high share of co-funding from sponsors / operators is required</td>
</tr>
<tr>
<td></td>
<td>Focussed at RES &amp; Fuel Cells, although there are talks to include CCS</td>
</tr>
</tbody>
</table>

### Funds in support of ETS

#### Innovation Fund

- **What is available before 2028**
  - Budget depends on auction price of emission allowances; if €15/t, budget could be €10B
  - Expected to cover up to 60% of relevant costs or 15% of total budget
  - Aimed not only at CCS, but also at other renewable energy projects
  - Expected budget could be sufficient to fund only a few industrial CCS clusters, also considering funding competition

- **Eligibility Considerations**
  - Regulated by ETS Directive If payments possibility of upfront funding is maintained and milestone-based payments are not linked to verified storage, fund could be suitable for all phases.
  - CCS projects ranked by €/tCO₂ stored, no incentive to oversize transport infrastructure
  - Each CCS project has to implement the full chain
  - Capture rate of at least 85%
  - Projects have to demonstrate that they could start operations within 4 years from funds reception
  - Exploration permit procedure must be underway

#### Unspent NER 300 funds

- Up to €550m, expected to be deflected to EDP InnovFin
**EU Structural and Investment Funds (ESI)**

<table>
<thead>
<tr>
<th>What is available before 2020</th>
<th>...and after 2020</th>
<th>Eligibility Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Regional Development Fund (ERDF) &amp; Cohesion Fund (CF)</td>
<td>• A collective budget of about €55B by 2020, and About €4B is allocated to financial instruments other than grants</td>
<td>• Member States responsible for setting up programs</td>
</tr>
<tr>
<td></td>
<td>• Future of ESI funds linked to Multiannual Financial Framework (MFF) review</td>
<td>• Investment to achieve the reduction of GHG emissions from activities listed in Annex I to the ETS Directive is not supported, hence CCS is excluded</td>
</tr>
<tr>
<td></td>
<td>• Can cover up to 50% of project cost</td>
<td>• As an exception to the above, CCS activities fall within scope if they are for research, development and testing of new products and processes</td>
</tr>
<tr>
<td></td>
<td>• Mutually exclusive</td>
<td>• Similarly, it may be possible to fund CCS through the ERDF as a Research, Technological Development and Innovation (RTDI) activity, provided the relevant Member States include it in their research and innovation strategies for smart specialisation, mostly still under development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Additionally, the Cohesion Fund is aimed at Member States whose GNI per inhabitant is less than 90% of the EU average</td>
</tr>
</tbody>
</table>

**Eligibility considerations**

- Focus on Research & Innovation (TRL 4-7), commercial industrial CCS is TRL 8-9
- It is believed that future calls in the current framework programme (i.e. in the period 2018-19) may be relevant for storage appraisal and other pre-FID work

**Horizon 2020**

- €77B in this MMF
- Each grant typically €1-20m
- €5.4B in this MMF
- Also offers loans and guarantees among a number of debt instruments

**Connecting Europe Facility (CEF) – Energy**

- For Projects of Common Interest (PCI) – route pursued by the Gateway project
- May be relevant for CO2 transport, but cross-border impact should be demonstrated, hence it may be more useful for connecting future CCS clusters, rather than for creating individual ones

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**Other EU funds**
APPENDIX 2: MODELLING ASSUMPTIONS

Industrial cluster

- The Rotterdam industrial cluster archetype was developed considering the industrial emitters in the area as shown below.

Figure 13: Industrial emitters in Rotterdam

P15 and P18 gas fields are included in the assessment as storage sites. Further information on the potential CO2 storage cluster offshore Rotterdam is shown below.

Figure 14: Offshore gas fields near Rotterdam

TAQA was awarded the P18-4 CO2 storage permit in 2003. The potential of CO2EOR in the RUN FIELD under P15-ACD needs evaluation. The potential of CO2 storage in aquifer formations in P15 P18 needs evaluation.

Source: Bellona, 2016, Manufacturing Our Future: Industries, European Regions and Climate Action

Source: Chris Gittins (TAQA), 2016, Short term offshore CO2 storage possibilities
### Key cost assumptions

- Capture costs are based on the median capex, opex, gas and electricity requirements for a variety of energy-intensive industries (Source: Element Energy for DECC and BIS, 2014, Demonstrating CO$_2$ capture in the UK cement, chemicals, iron and steel and oil refining sectors by 2025) and scaling algorithm is based on standard engineering rule of thumb – i.e. \( \text{cost}_A / \text{cost}_B = (\text{scale}_A / \text{scale}_B)^{2/3} \).  
- Transport and storage costs are based on high-level estimates provided by the potential project developers in Rotterdam and consistent with the figures included in the SET Plan.  
- Decommissioning costs are assumed to be 25% of capital costs.  
- Loan interest rate and return on equity are assumed to be 3% and 12%, respectively.

### Illustrative costs of Rotterdam industrial CCS cluster

#### Table 6: “Archetypal” Rotterdam industrial CCS cluster – pre-FID and construction costs (€million)

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Pre-FID</th>
<th>Constr.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capture: Not required in the first phase</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Transport: Onshore backbone pipeline connecting ROAD to OCAP pipeline</td>
<td>€2</td>
<td>€45</td>
</tr>
<tr>
<td>Transport: Offshore pipeline (Maas to P18-A platform)</td>
<td>€3</td>
<td>€70</td>
</tr>
<tr>
<td>Storage: Further appraisal is not required - only FEED</td>
<td>€5</td>
<td>-</td>
</tr>
<tr>
<td>Storage: Mods to P18-A platform and P18-4 field single well</td>
<td>-</td>
<td>€35</td>
</tr>
<tr>
<td><strong>Second Phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capture: 3Mt/yr (in total) from industrial emitters in Rotterdam</td>
<td>€20</td>
<td>€570</td>
</tr>
<tr>
<td>Transport: Feeder pipelines</td>
<td>-</td>
<td>€50</td>
</tr>
<tr>
<td>Storage: Appraisal fof P18 and P15 gas fields for cluster expansion</td>
<td>€30</td>
<td>-</td>
</tr>
<tr>
<td>Storage: Mods to P18-2 field wells (2 for injection of CO$_2$ and 2 for observation/monitoring)</td>
<td>€5</td>
<td>€30</td>
</tr>
<tr>
<td>Storage: Mods to P18-A platform for more CO$_2$ wells</td>
<td>€5</td>
<td>€10</td>
</tr>
</tbody>
</table>

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39 Source: APEC, 2013, Building capacity for CO2 capture and storage in the APEC region: A training manual for policy makers and practitioners