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Developing a Pilot Case and Modelling the Development of a Large European CO_2 Transport Infrastructure - The GATEWAY H2020 project

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Abstract

The H2020 GATEWAY project aims to develop a comprehensive model Pilot Case which, intentionally, will pave the ground for CCS deployment in Europe. It will result from the assessment of, technical, commercial, judicial and societal issues related to a future CO2 transport infrastructure. The Pilot Case derived on this basis, will emphasize a gateway for CO2 transport in the North Sea Basin. Four potential pilot cases have been evaluated through a combination of techno-economic modelling of the individual cases and evaluation against more qualitative criteria. The chosen Pilot Case, Rotterdam Nucleus, will be refined and developed during the remaining period of the GATEWAY project. To maximise impact, the GATEWAY project adapts its work to lay the foundation for a future application to a European 'Project of Common Interest' (PCI). Continuous dialogue with the most relevant stakeholders is an important part of GATEWAY, as a Coordination and Support Action (CSA) H2020 project.

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Peer-review under responsibility of the organizing committee of GHGT-13.

Keywords: the GATEWAY project; CCS; Pilot Case Development; PCI; Horizon 2020; climate mitigation; CO2 transport infrastructure

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Abbreviations

CCS	Carbon capture, transport and storage	NSBTF	North Sea Basin Task Force
CEF	Connecting Europe Facility	PCI	Project of Common Interest
CNS/SNS	Central/South North Sea	TEN-E	Trans-European Energy Networks
DG	Decision Gate	T&S	Transport and storage
EOR	Enhanced Oil Recovery	ZEP	Zero Emission Platform
ETIP	European Technology and Innovation Partnership		
GHG	Greenhouse gas		
H2020	Horizon 2020, the European Commission's 8th framework programme for research and innovation		

1. Introduction

The European Union has set itself a long-term goal of reducing greenhouse gas (GHG) emissions by 80-95% when compared to 1990 levels by 2050 [1]. In December 2015, at the United Nations Climate Change Conference (COP 21), the Paris Agreement was adopted, whereby Parties agreed to "pursue efforts" to limit global temperature increase caused by human-induced climate change to 1.5 °C [2]. The agreement calls for zero net anthropogenic greenhouse gas emissions to be reached during the second half of the 21st century. At the same time, the demonstration of carbon capture and storage (CCS) technologies, highlighted to be an indispensable mitigation technology by the vast majority of global climate models, is losing traction, especially in Europe [3].

Although a full chain has yet to be demonstrated in Europe, CCS technology is available and could be applied in power generation sector as well as in industrial sectors, but so far there has been no viable business case to facilitate deployment. ETIP ZEP (see section 3.1), advisor to the European Commission on the research, demonstration and deployment of CCS, has put considerable effort in to developing a strategy and providing an action plan for the future CCS deployment in Europe [4][5]. The actions proposed by ZEP are: 1) Decouple the capture of CO2 from transport and storage (T&S); 2) Develop CCS in phases through (expanding) infrastructure hubs; 3) Optimize available funding and create mechanisms to commercialize CCS; 4) Engage Member States through 2050 decarbonisation plans to enable the development of T&S infrastructure.

The 2-year H2020 project GATEWAY, which started in May 2015, aims to accelerate the deployment of CCS, notably by developing a model case aimed at commencing an initial cross-border gateway connecting available CO2 sources and possible sinks.

The objectives of GATEWAY are:

1. To define a Pilot Case, providing a model for establishing a European CO_2 infrastructure project, targeting a gateway transferring CO_2 from source to sink.
2. Define a subsequent EU CO_2 Project of Common Interest (PCI), which if selected, can benefit from accelerated permitting procedures and improved regulatory conditions, and may be eligible for financial support from the Connecting Europe Facility (CEF).
3. Align the stakeholder's interests and engage Member States strategies.
4. Develop a business case for the Pilot Case project by addressing the risks and proposing measures for de-risking as well as assessing the funding needs and proposing possible financing mechanisms.

The GATEWAY Pilot Case development plan is adopting a phase-gate process development model. The project has recently reached its second decision gate (DG2, see Fig.1). This paper will present some of the work and results obtained within the first half of the project. First, an explanation of the concept 'Project of Common Interest' will be outlined. Secondly, public and private stakeholders and their strategies to which GATEWAY has sought alignment, are presented. Here, also CCS challenges related to legal issues are included.

The criteria for pre-screening are included in section 5. Finally, the current status and outlook of GATEWAY will briefly be described.

2. Projects of Common Interest

Projects of Common Interest (PCIs) are a development of Regulation (EU) No 347/2013 of the European Parliament and of the Council, often referred to as the new TEN-E Regulation, which provides guidelines for trans-European energy infrastructure [6]. Within this regulation, twelve strategic priority corridors and geographic areas were defined, dealing with infrastructure in electricity, gas and oil, as well as electricity highways, smart grids, and CO_2 transportation networks. PCIs were established in 2013 to support these developments between 2014 and 2020 and beyond [7].

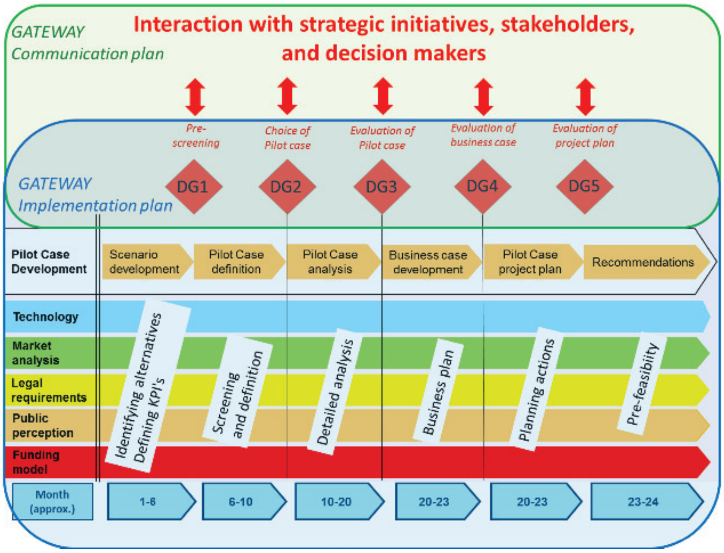

Fig. 1. The GATEWAY Pilot Case implementation plan outlining the phases of the project, and the different areas of assessment.

The first pool of PCIs contained 248 projects, none of which dealt with the strategic priority corridor related to the development of a CO_2 transportation network [6]. The list is revised every two years, allowing new projects to apply to obtain the PCI status, and requiring prior PCIs to re-apply to maintain their PCI status. These projects are permitted to seek funding from CEF, a source of funding totalling €4.7 billion meant to encourage public and private funding of trans-European networks [7]. Aside from the CEF financial support, PCIs may also benefit from more efficient permitting procedures, including a single national competent authority (the one-stop-shop) for permitting, set time limits for permitting procedures, more transparency and better public participation, and a more streamlined environmental assessment procedure [8].

3. Alignment of the GATEWAY project with central European actors and regulations

Any PCI requires both strong commitment by at least two Member States, in addition to a clear demand from industry for the infrastructure in question. In light of these requirements, the GATEWAY project has undertaken considerable effort to interact with both government and industry representatives. In particular, the project has been interacting with the Zero Emission Platform (ZEP), the North Sea Basin Task Force (NSBTF) and the European Commission's work on PCI development.

3.1. The Zero Emission Platform

ZEP is a group of industrial stakeholders that has recently been transformed to a European Technology and Innovation Partnership (ETIP). ZEP advises the European Commission on CCS policies. In its *Executable Plan for enabling CCS in Europe* [5], ZEP describes three phases of the development of a large CO_2 infrastructure in Europe. The idea is to start with existing CCS demonstration projects in prime locations, and thereafter expand into other CO_2 hubs around Europe. Starting with CO_2 sources near the first project, the net of pipelines and connected CO_2 sources and storage sites will develop over several years, as illustrated in Fig. 2.

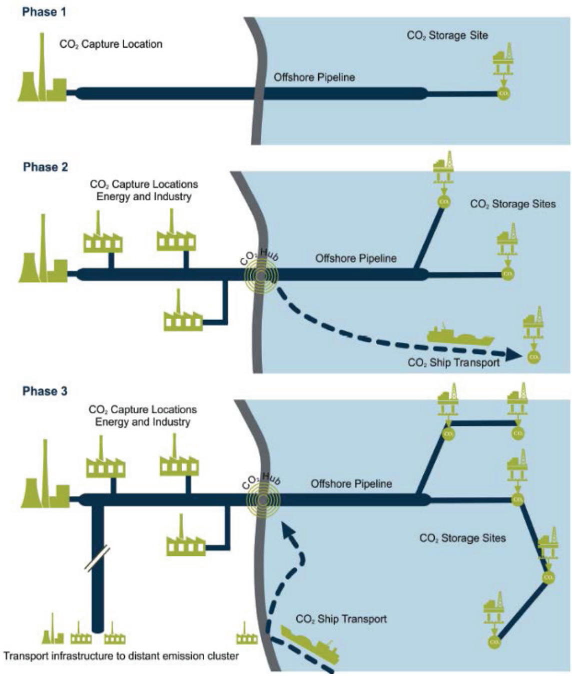

Fig. 3. ZEP's three phases of the development of a large CO_2 infrastructure in Europe. Phase 1) Deliver existing single source/ sink CCS demonstration projects in prime locations, which can be expanded into strategic European CO_2 hubs; Phase 2) Start sourcing CO_2 from nearby emitters to create CCS hubs; and Phase 3) Expand the hub over a wider region and potentially across neighbouring countries.

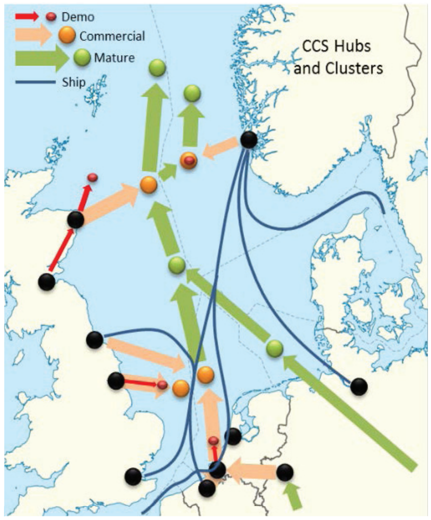

Fig. 3. NSBTF map of potential CCS hubs and clusters.

The reasoning for this cluster- and storage hub approach is the expected benefits from economies of scale. Industrial actors are often closely situated, and the approach allows industries to use a shared infrastructure. This is beneficial for all parties, and multiple and smaller CO_2 emitters are able to reduce their costs. Thus, a shared transport and storage infrastructure with additional/spare capacity can be an attractive investment for CO_2 emitters. ZEP describes four regions where the building of the CO_2 infrastructure can begin: the Rotterdam hub, the UK Southern North Sea hub, the UK Scottish hub, and the Scandinavia hub (see Fig. 3). The hubs are all situated around the North Sea, an area that is referred to as "a world class storage region" [9]. GATEWAY was developed in parallel with ZEP's executable plan and can be seen as a tool for kick-starting the execution of the plan.

3.2. The North Sea Basin Task Force

NSBTF is composed of public and private bodies from countries on the rim of the North Sea, aiming to develop common principles for managing and regulating the transport, injection and permanent storage of CO_2 in the North Sea sub-seabed. As of 2016, the NSBTF comprises members from Norway, UK, Germany, the Netherlands and Flanders in the north of Belgium. The NSBTF members all share an interest in the implementation of CCS and discuss strategies to forward CCS. Similarly to ZEP, NSBTF recognizes the North Sea Basin as the soundest place in Europe to start transport and storage of CO_2. The NSBTF also acknowledges that the countries bordering the North Sea need to coordinate and plan together to deliver an optimum network.

The NSBTF is currently engaged in the development of a 'Master Plan' for CO_2 transport infrastructure in Europe, and the GATEWAY project is complimentary to this initiative.

3.3. The European Commission's work on PCIs

To qualify as a PCI, each infrastructure type has specific criteria to comply with, which are set out in the Trans-European Energy Networks (TEN-E) regulations. However, these criteria were generally developed with reference to more established energy infrastructures such as natural gas pipelines and electricity transmission installations, and the application of these criteria to CO_2 transportation infrastructures had raised some practical questions. Since the release of the TEN-E guidelines in 2013, the European Commission has been working to provide further clarification on the process of identifying and selecting PCIs in the field of the Priority Thematic Area Cross-border carbon dioxide networks. The GATEWAY project has engaged with the Commission to align the projects' efforts in elaborating robust methodologies for calculating the costs and benefits of CO_2 transport PCIs.

3.4. European legal regulations

From a legal perspective, the project could face issues at several 'layers': international law, national law and local law. Change at one level, for example at the international law stage, will generally affect national and local issues and vice-versa. An important part of the project work is therefore to analyse potential issues and align with European legal regulations at all levels.

At the international level, countries' positive international CCS outlooks or international participation in CCS and/or CO_2 transport activity are essential. Also, at the international level is the issue of ratification of the London Protocol, an international agreement that prohibits the dumping of wastes at sea, including the export of waste for such disposal [10]. Offshore storage of CO_2 for the purpose of CCS has been addressed in an amendment to Annex I of the London Protocol. However, Article 6 of the Protocol currently forbids the international transboundary transportation of CO_2 for offshore storage. Although an amendment to address this restriction has been proposed to the Protocol's Parties, it becomes binding only after ratification by two-thirds of the Protocol's current 46 Parties. Presently, only Norway and the UK have signed the amendment.

At the national level, the success of the CCS industry will be influenced by: the existence of favourable national policy and legislation (law and policy); financial commitments and subsidies on offer (economics); and the presence of a suitable liability regime being the division of risk exposure between public and private actors (liability).

Finally, at the local level, issues influencing CCS success include planning law and permitting, such as stable application procedures, demonstration projects and experience with industry. This multi-level approach will be used in the assessment of legal issues for the GATEWAY Pilot Case.

4. Project selection and pre-screening of Pilot Case alternatives

To define a Pilot Case, it was considered important to first look into a range of possible cases with different types of configurations. Both in terms of technical aspects (overall size, types of sources and sinks, pipeline length etc.), but also in terms of some of the key criteria, such as legal issues, public acceptability and structure of a business case. Each of the candidate cases were also designed to meet the minimum PCI requirements.

The final candidate cases were reduced to four (see

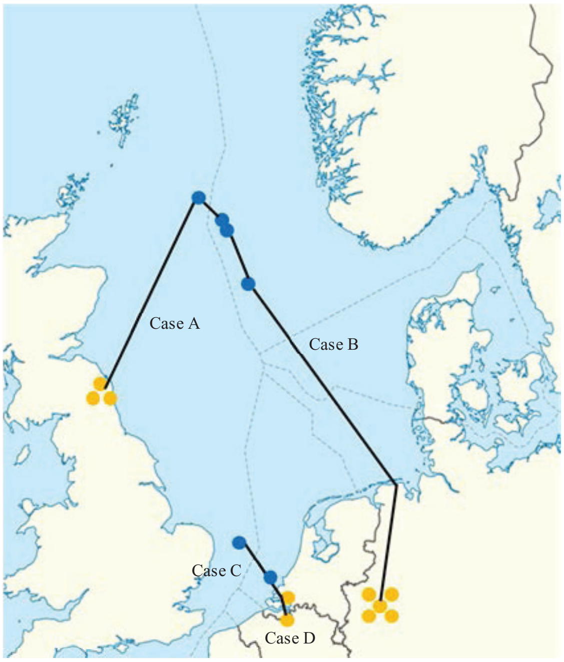

Fig. 4. Diagram illustrating the location of possible candidate cases. Yellow dots portray sources of CO_2, while blue dots signify storage locations with black lines showing pipeline routes.

case A-D in Fig. 4) and these were then subjected to an analysis of their merits against some key criteria (see section 5).

4.1. Case A: UK-Norway EOR

The UK-Norway EOR-case proposes a pipeline linking a varied cluster of CO_2 sources in the North East of England to Enhanced Oil Recovery (EOR) opportunities in the UK and Norwegian sectors of the Central North Sea (CNS).

There is a huge but fleeting opportunity to use CO_2 to produce significant additional levels of oil from existing CNS fields. This could amount to a further 30% of all CNS historical production with a total value of €100s bn, but the economic window for exploiting this opportunity is during the next 10 years, during the fields' decline.

4.2. Case B: German Backbone

The German Backbone case links the major concentration of CO_2 emissions in Western Europe (in the Ruhr valley in Germany) to the main North Sea oil fields in the Central North Sea. This is a major CO_2 pipeline project to serve as a backbone for the development of a full CCS network around Western Europe and the North Sea area.

4.3. Case C: Rotterdam Nucleus

The Rotterdam Nucleus case is based on the developing nucleus of Rotterdam, with the RCI initiative, existing ROAD project and potential additional cluster connections (see the CAR pipeline, Case D). The CO_2 network is extended out to gas field "Fizzy" in the UK Sentral North Sea (SNS) sector 50 to facilitate gas production with CO_2 separation and storage. By doing this, 3.7 bcm natural gas can be produced (current value $800m) with potential for considerable further similar extensions. The importance of CCS in this context is its ability to facilitate the development of a further significant gas field. This project also has the potential to demonstrate a valid income stream for CCS infrastructure which can enable and encourage international CO_2 infrastructure.

4.4. Case D: CAR pipeline

The CAR pipeline case involves the development of a CO_2 pipeline, with the necessary compression and monitoring equipment, to transport CO_2 from a centralized location in the Antwerp region through the Port of Rotterdam and then to gas fields in the P18 block of the Dutch continental shelf for storage. The total length of the pipeline is approximately 140 km, split into three sections with different pipeline capacities and pressure operation regimes. For ease of management and operation, the three sections have been given individual titles, but should be considered as an individual PCI known as the CAR Pipeline.

5. Key Criteria

The four potential cases were evaluated for their merits against seven distinct criteria on a generic basis. The key criteria for evaluating the candidate Cases were as follows: 1) reflects ZEP's strategic plan, such that it demonstrates a basis for spawning future expansion and fits in with high level CCS vision; 2) meets the PCI criteria, so that it is eligible as a PCI; 3) the technical risk profile, reflecting the difficulty in physically achieving the project and whether the technical risks are financeable; 4) has stakeholder support to push the project through to fruition; 5) is financially viable according to a first-stage project financial model and basic economic tests; 6) has no legal obstacles, i.e. substantial legal problems due to project specifics; and 7) potential public acceptance in terms of known geographical indications of public opinion and of key opinion formers. The process upon which the pilot cases were evaluated was through a combination of techno-economic modelling of the individual cases, and through expert workshops to assess the pilot cases against the more qualitative criteria. The overall scores in the main categories are shown diagrammatically in Fig. 5, and some of the main criteria are elaborated below.

- **PCI criteria and consistency with the ZEP strategic plan:** The candidate Cases had all been chosen with their strategic location and expansion potential in mind, so all were able to meet the minimum criteria for the PCI eligibility and to some extent fit in with the ZEP strategic plan. The German Backbone was considered the boldest with the greatest development potential, whilst the CAR project can be seen as the most regional with perhaps the lowest further development potential.

- **Technical risk profile:** For the technical risk profile, the key test was whether the technology associated with the CCS project is proven and deliverable or whether there are elements which are novel or unproven at scale or which represent a significant complexity. An assessment of the synchronization / matching of source(s) and sink(s) and the availability of CO_2 to the project was also performed.

- **Legal Issues:** This topic encompasses a range of legal issues which could provide obstacles or show-stoppers for certain projects. Issues considered include international participation, the London Protocol, National Law & Policy, Commercial Law and Planning law and Permitting Issues. Liability issues have also been discussed but this point is recognized to be a continuing issue for all countries.

- **Stakeholder support:** The assessment of the candidate Cases in this category was not necessarily for existing supportive stakeholders (as in the case of the CAR pipeline) but rather for the potential for Member State support and for the ability to find supporting commercial stakeholders for the outlined project.

- **Financial viability:** The candidate Cases have been compared against a number of economic criteria, including their revenue prospects, their appetite for capital funds, the perceived project risk/reward balance and any foreseen commercial obstacles. This initial assessment was followed up by the development of an initial GATEWAY economic model which allowed the Cases to be compared on any standard economic parameters (such as NPV or project return).

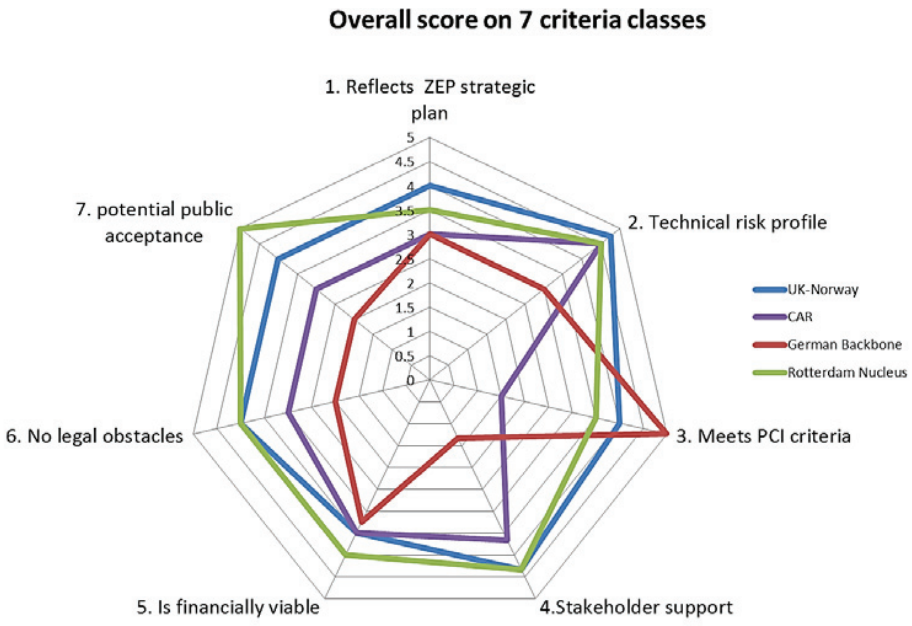

Fig. 5. Diagrammatic representation of the four Cases in seven criteria, where the highest positive score (5) is furthest from the centre.

- **Public Perception:** In order to identify which factors would be important for the public perception of the Pilot Case, a systematic review of 30 existing studies on public perception of CO2 transport was carried out. It points out that it is very likely that the public perception of the Pilot Case to a large extent will be influenced by the risk perceptions, benefit perceptions and trust of the public who will be affected by the CO2 transport network. During the remaining period of the GATEWAY project, a design for performing a reliable assessment of the public perception of the Pilot Case will be developed which can be applied in order to facilitate a successful construction and deployment of the Pilot Case.

6. The Chosen Pilot Case and the way forward

Based on the scoring results and discussion, it was decided to combine both Case C, the Rotterdam Nucleus, and Case D, The CAR pipeline (see Fig. 6). Combining these two pilot cases enabled both the opportunity for large scale decarbonisation of two of Europe's most prominent industrial hubs, Rotterdam and Antwerp, but also linking the potential financial gains of high CO_2 content gas fields in the UK SNS. Nevertheless, the Pilot Case is still referred to as 'Rotterdam Nucleus'.

Whereas the Dutch continental shelf in the North Sea has considerable potential for CO_2 storage, both in gas fields and saline aquifers [11], CO_2 storage options in Belgium are understood to be limited. Belgium has some potential for CO_2 storage in coal seams, however this form of CO_2 storage has yet to be demonstrated, and these storage areas are located onshore, which can cause planning issues because of public concerns of CO_2 storage [12]. If CCS is to be considered an option for decarbonizing the Port of Antwerp, there is a clear rationale for developing a CO_2 pipeline from Antwerp to Rotterdam, where from the CO_2 can be transported to offshore storage locations.

The rationale for linking the Port of Antwerp with the Port of Rotterdam and offshore storage sites, is further supported by advanced plans to develop the 'ROAD' large scale CO_2 capture project at a coal-fired power plant in Rotterdam. As part of this project, the planning and permitting requirements for a 18km CO_2 pipeline have been acquired, which passes from the Maasvlakte area of the port, to an expended gas field which has the necessary permit requirements for CO_2 storage. In addition, there is already an existing CO_2 pipeline which runs through the Port of Rotterdam. The OCAP pipeline (outlined in Fig. 6) transports approximately 400 ktCO_2 per year from two pure CO_2 sources (a refinery and a bioethanol plant) to greenhouses to the north of Rotterdam. The capacity of this pipeline is understood to be far greater than is currently utilized.

The development of a multi-user CO_2 transportation infrastructure in the Rotterdam harbor, which can open the

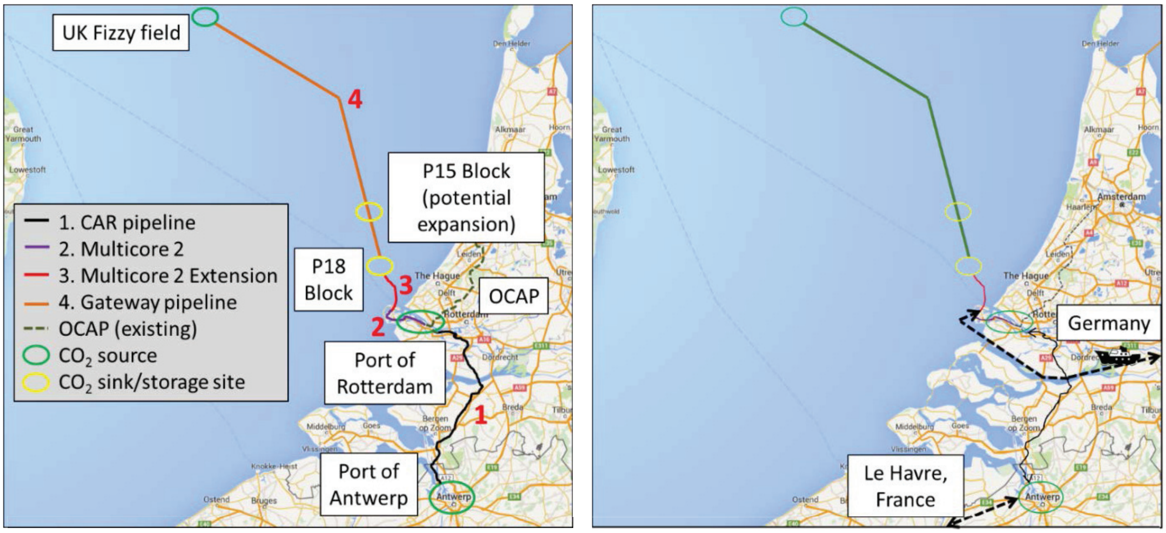

Fig. 6. The diagram to the left shows pipeline routes and fields for the Pilot Case, Rotterdam Nucleus. Possible future extensions are added in the diagram to the right including a shipping route connecting Germany (Ruhr Valley) to Rotterdam and a connection of Antwerp to Le Havre in France.

potential North Sea storage sites, could be interesting for industrial hubs beyond Antwerp and Rotterdam itself. The heavy industrial area of the Rhine region is located approximately 200 km from the port of Rotterdam, and an inland shipping or pipeline route would be the shortest route to transport CO_2 from the region to offshore storage sites. A future connection to Le Havre in France is another obvious upscaling opportunity.

The Rotterdam Nucleus Pilot Case will be refined and developed during the remaining period of the GATEWAY project, with key technologies and the final proposed definition of the project along with a Business Case description. In October 2016, the European Commission is expected to provide additional guidance on the application and evaluation process regarding CO_2 transport PCIs. Based on this guidance, the GATEWAY project will contribute to the development of a PCI prospectus of the Rotterdam Nucleus for submission to the European Commission in 2017. The successful submission is of course dependent on commitment by the relevant Member States and prospective owners/operators of the infrastructure.

Acknowledgements

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