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Abstract

Within the GATEWAY project, Task 2.1 “Public perception of CO_2 infrastructures” is part of Work Package 2 (WP2) “Derisking – innovation and techno-economic validation” and aims at providing material which is useful for assessing the public perception of the potential pilot cases. For this purpose a review of European public perception studies pertaining to CO_2 transport was carried out. In this report, primarily the selection of the studies is described and an overview of the chosen studies is given. Afterwards the results of the review are explained and finally it is explicated which conclusions can be derived for the assessment of potential pilot cases.

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1 BACKGROUND

CO_2 capture and storage (CCS) is perceived worldwide and in the European Union (EU) as a key technology for greenhouse gas (GHG) emissions mitigation. However, for the further development of CCS projects in Europe the development and construction of a cross-border CO_2 transport infrastructure so as to efficiently connect CO_2 sources to sinks is an important precondition. The GATEWAY project aims at facilitating the development of a CO_2 cross-border infrastructure network by developing a pilot case for a European CO_2 transport infrastructure, defining a project of common interest (PCI) and developing a business for the pilot case. The first step of the pilot case definition is the selection of 2-3 potential pilot cases which will be evaluated with regard to five main axes: (1) technology availability and costs, (2) market analysis, (3) legal and regulatory framework, (4) public perception and (5) funding mechanisms (cf. M1 Pilot case development plan).

Against this background, Task 2.1 "Public perception of CO_2 infrastructures", which is part of Work Package 2 (WP2) "Derisking – innovation and techno-economic validation", aims at providing material which is useful for assessing the public perception of the potential pilot cases. For this purpose a review of European public perception studies pertaining to CO_2 transport was carried out. The selection of studies, the results of the review and the conclusions which can be derived for the assessment of potential pilot cases are explained in the present report "Deliverable D2.1 – Part 1". The second part of the Deliverable D2.1 "Design for assessing public perception of the Pilot Case" was originally planned to be finalized also in month 12 of the project. However, since the project consortium assumes that recommendations on the public perception specifically of the pilot case will be more helpful, it was postponed to the Phase 3 "Building the business case" (cf. M1 Pilot case development plan).

2 SELECTION OF STUDIES

The aim of the review is to provide material which is useful for assessing the public perception of potential pilot cases for a European CO_2 transport infrastructure. In general, CO_2 can be transported by pipelines, trucks or ships. However, the pilot case which will be developed in the GATEWAY project should fit the criteria for a PCI, which are described in the REGULATION (EU) No 347/2013 OF THE EUROPEAN PARLIAMENT. One of the criteria which must be met by a PCI is that it must involve a pipeline linking more than one source to more than one storage location (cf. M1 Pilot case development plan). Therefore, the review of European public perception studies pertaining to CO_2 transport was focused on studies on the public perception of CO_2 pipelines.

2.1 Selection criteria

The studies considered in the present review were selected according to the following criteria. First and foremost, they had to deal with pipelines, not only in their descriptive parts but also in their analytical parts or discussions of their results. The aim was to identify studies presenting insights into the public perception of CO_2 transport via pipelines based on original data.

For this reason, in addition to all studies explicitly dealing with the public perception of CO_2 pipelines and presenting original data we also included studies not discussing pipelines explicitly but nevertheless reporting (often anecdotic) evidence of the perception of such pipelines. In order to broaden the altogether limited scope of data we also included studies from non-EU countries. As comparative studies show, differences between EU and non-EU countries exist but it is by no means clear whether they are random or whether they can be systematically explained with historical or political path dependencies of European versus non-

European countries. We also only included studies reporting empirical findings rather than theoretical ones or reviews.

Studies that do not contain relevant original data were not considered. So studies that explained the transportation aspects of the CCS technology but subsequently did not discuss perception issues of pipelines separately [1-3] were excluded from the analysis. Likewise we excluded a number of studies on focus group-style research mentioning pipelines as part of the information packages for their respective focus groups but then not discussing results specifically relating to them [4] [5] [6]. In neither case it can be safely established whether the attitudes reported are shaped to any significant degree by the transportation elements of CCS.

Proceedings were only included when they were not followed up by a separate article. An exception was [7, 8]. Both studies draw on the same empirical data and also structure and content show that [7] is a revised and extended version of [8]. However, the anecdotal evidence on pipelines reported in both studies stresses slightly different aspects, which are nonetheless interesting to note. For this reason, both studies are included in the present review but treated as a single contribution.

2.2 Selection procedure

In order to identify studies dealing with the public perception of CO_2 pipelines the following selection procedure was applied. First, in May/June 2015 we searched Web of Science[1] for keywords frequently used in the context of public acceptance and social science research on CCS as suggested by [9]: acceptance, acceptability, perception, attitude, public opinion, each combined with CCS, carbon capture, CO_2 storage.[2] Additional studies were identified via a snowball system.

Second, all studies identifies in the first step were searched for the terms ‘transport’ and ‘pipelines’ and automatically coded respectively using the text analysis software MAXQDA. The automatic search and coding also included morphologically related terms such as ‘transportation’ or ‘pipelines’. Next, all coded passages were checked directly to find out whether the studies contained relevant data or not. Thus, we identified 30 studies presenting original data on the public perception of CO_2 transportation in pipelines, whereby [7] and [8] count as one contribution (cf. Table 0.1).

[1] After this comprehensive search in May/June 2015 Web of Science was checked regularly in order to find out whether new articles were published.

[2] The keywords ‘pipeline’ and ‘transport’ were not used because a first test showed that CO2 transport via pipeline is a rather marginal topic. Searching for respective keywords would have excluded many relevant studies.

3 OVERVIEW OF THE STUDIES

3.1 Numbers of publications covering public perception of CO_2 pipelines over time

The earliest article which includes results concerning public perception of CO_2 pipelines was published in 2004 [10] (cf. Figure 3.1 and Table 0.1).[3] Until 2010 six studies covering public perception of CO_2 pipelines were published, eight papers were released in 2011[4] and 16 articles were published between 2012 and 2015. However, the first and only article which focused completely on the investigation of public perception of CO_2 transportation in pipelines was available in 2014 [11]. Prior to this an article was published in 2012 which examined the importance of a CO_2 pipeline for the public perception of CCS in general [12].

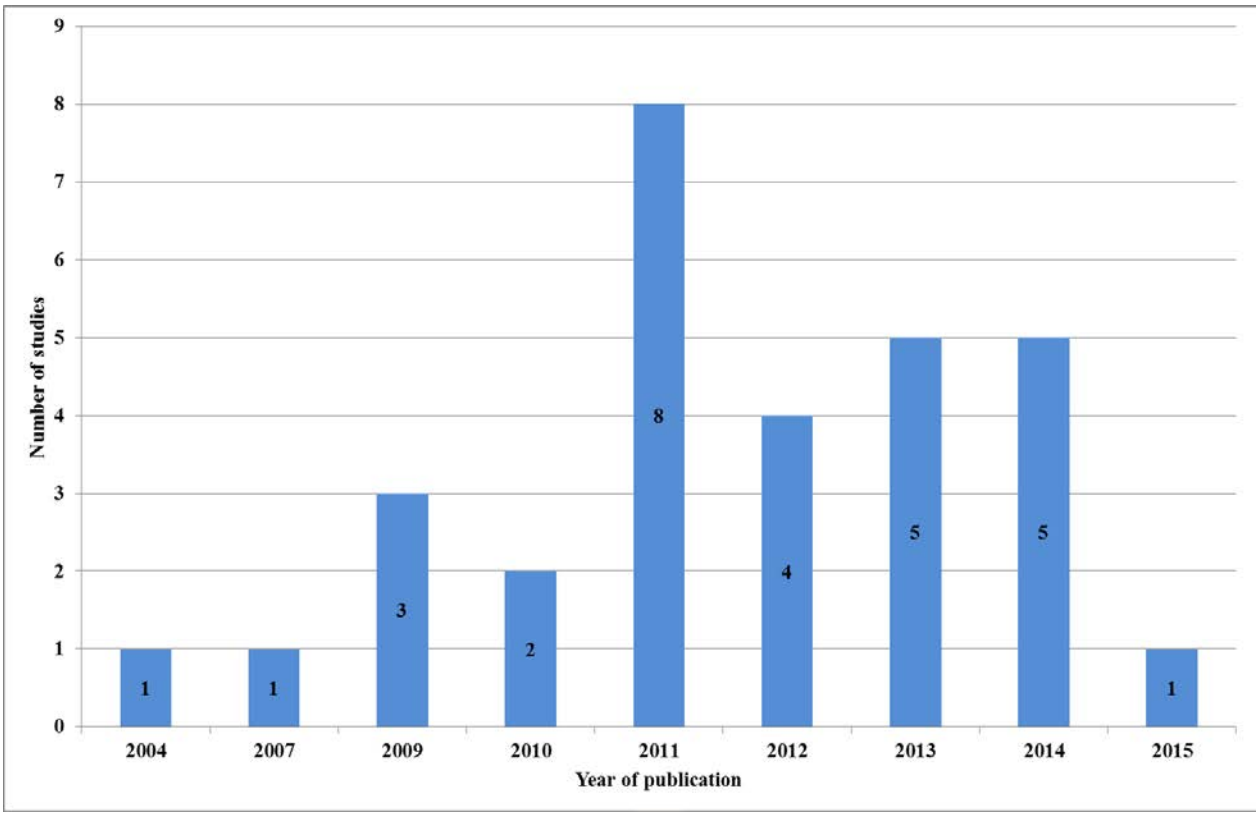

Figure 3.1: Numbers of publications with empirical evidence on the public perception of CO_2 pipelines over time

[3] The earliest article which was published on public perception of CCS in general was published in 2002 [9].

[4] All of them were proceedings papers to the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), which was held in September 2010 in Amsterdam. This reflects that the attention of the GHGT conferences for the topic of public perception of CCS increased over time. However, compared to technical and economic aspects of CCS the space which is given during the GHGT conferences for the presentation and discussion of public perception, legal or regulatory aspects is still very small.

3.2 Countries and regions analyzed

Most of the studies with empirical evidence on the public perception of CO_2 transportation in pipelines were published from the Netherlands (cf. Figure 3.2 and Table 0.1).[5] Seven studies were published from the UK, six studies from Germany, four studies from Spain and three studies from Australia and the US. Two studies were released from Japan and Poland and two studies include several European countries. In each case one study covering aspects of public perception of CO_2 pipelines is available from North America, Belgium, Canada, China, France, Greece, Indonesia, Japan, Norway and Romania.

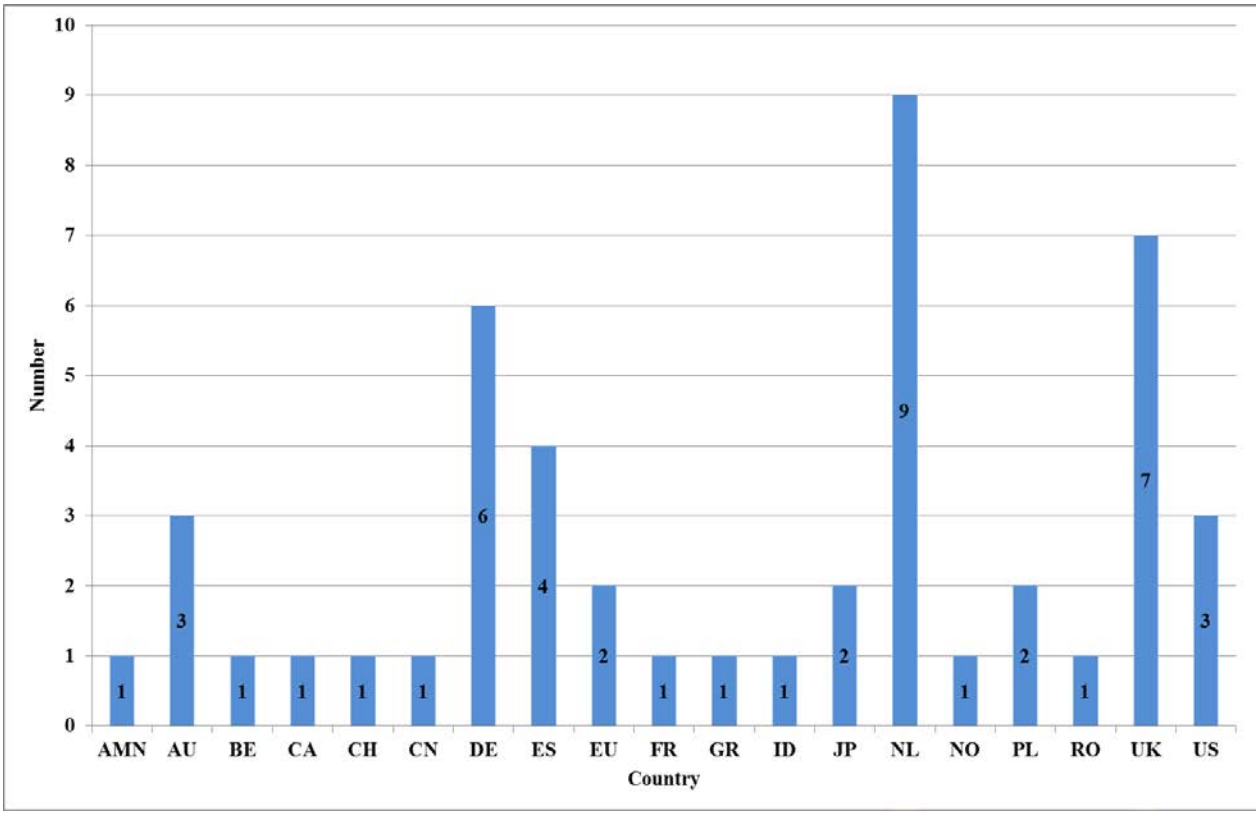

Figure 3.2: Countries and regions analyzed in the studies with empirical evidence on the public perception of CO_2 pipelines

3.3 Foci of research

In general, the foci of research of the 30 studies can be grouped into three different categories (cf. Table 0.1):

(1) Attitudes, knowledge and the impact of information,
(2) Procedures and communication,
(3) Research-related methodological questions.

The vast majority of studies (23) investigate attitudes, knowledge and the impact of information (cf. Table 0.1). Attitudes and knowledge may refer to CCS and its three elements – capture, transport, and storage – (e.g. [11-13] as well as the complete CCS chain (all others), CCS in a broader context (e.g., [14]), CCS and climate change or CCS and other mitigation

[5] This is related to the fact that the investigation of public perception was an important part of the Dutch CCS research programs CATO and CATO-2 (cf. http://www.co2-cato.org/).

options [15]. Conceptually closely related to this type of study are those investigating the impact of information on the formation of attitudes towards CCS and its components so that they are treated in this review with the analysis of attitudes and knowledge in one category.

The category 'procedures and communication' comprises six studies concerned with empirical cases of public engagement in CCS projects and two studies deal with research-related methodological questions, i.e. in these studies researchers reflect on their own work.

From the 30 studies presenting original data on the public perception of CO_2 transportation in pipelines, only one focuses on public perception of CO_2 pipelines as central subject of research [11]. Two studies [12, 16] investigate to what extent the public perception of CCS is influenced by mentioning that the captured CO_2 will be transported by pipeline. [10], [15, 17-26] and [27] treat the public perception of CO_2 pipelines systematically (but not centrally) as standardized survey or interview questions or themes in moderated discussions. With the exception of [28], which presents the perspective of a project developer, all others present anecdotic evidence, either as verbatim quotation of recorded evidence or as description, where the origin and motivation of the quotation are somewhat unclear. In these studies, which employ qualitative methods such as qualitative interviews, deliberative mini-publics or case studies, it does not become clear whether the issue of pipelines and storage was deliberately raised by the researchers, interviewers or moderators, or by the participants themselves.

3.4 Methods applied

The studies in this review covered a wide range of methodology. 14 studies were qualitative. They used qualitative interviews, case studies and deliberative mini-publics (cf. Table 3.1 and Table 0.1).

Qualitative interviews are usually open or semi-structured. Open means that the interviewer only asks a standardized initial question while the course of the interview is then determined by the interviewee's response. Semi-structured interviews use a standardized set of questions and an open part [29]. In the studies reviewed here, the interviews sometimes are only referred to as 'qualitative' and the precise type is not specified.

Case studies consist of descriptions and analyses of public engagement in empirical cases of (attempted) CCS deployment.

Deliberative mini-publics include all methods by which a group of people discuss a certain issue, usually guided by a moderator. These can be well structured and standardized processes such as focus groups or citizens panels, in which "a group of people are provided with detailed briefing on particular topics before being asked in an interactive and deliberative setting about their attitudes" [11], referring to [30] and [31]. It can also be less structured and/or standardized processes such as workshops or public discussion events. Especially the more structured processes are "suitable for exploring the awareness, knowledge and initial attitudes of lay people concerning CCS, but are rather unsuitable for identifying causal relationships between relevant influencing factors and attitudes towards CCS" [25].

10 studies can be classified as quantitative. They used standardized surveys, standardized surveys with information or Information-Choice Questionnaires (ICQs) (cf. Table 3.1 and Table 0.1). Standardized surveys include a set of closed-ended questions[6] posed to a representative

[6] Closed-ended is a question for which a researcher provides a suitable list of responses which can be answered for example with "yes" or "no" or rated on a Likert scale e.g. ranging from 1 (=strongly disagree) to 7 (=strongly agree).

sample of a certain population. They allow for covering a large number of cases but carry the risk of pseudo opinions, i.e. opinions people volunteer even though they have little or no knowledge about the topic at hand [19, 25, 32].

Table 3.1: Methods applied in the studies with empirical evidence on the public perception of CO_2 pipelines

Study	Quantitative methods			Qualitative methods				
	Standardized survey	Standardized-survey with information	ICQ	Semi-structured interviews	Unspecified interviews	Case studies	Standardized mini-publics	Not standardized mini-publics
Anderson et al. [17]				✓				
Bradbury et al. [45]	✓				✓		✓	
Brunsting et al. [18]						✓		
De Best-Waldhober et al. [19]	✓		✓					
De Best-Waldhober et al. [39]	✓		✓		✓			
De Best-Waldhober et al. [15]			✓					
Dowd et al. [20]		✓						
Duetschke et al. [16]		✓						
Einsiedel et al. [14								✓
Gough et al. [11]							✓	
Ha-Duong et al. [37]						✓		✓
Hund et al. [46]					✓		✓	✓
Johnsson et al. [21]	✓							
Kuijper et al. [28]						✓		
Liang & Reiner [22]	✓				✓			
Mabon et al. [38]					✓			
Mander et al. [23]	✓						✓	
Oltra et al. [43]							✓	
Palmgren et al. [10]	✓	✓		✓				
Riesch et al. [42]							✓	
Roberts & Mander [44]	✓						✓	
Schumann et al. [26]	✓							
Schumann [25]		✓						
Setiawan &Cuppen [27]				✓				
Shackley et al. [24]		✓						
Simpson & Ashworth [40]						✓		✓
Ter Mors et al. [34]			✓				✓	
Terwel et al. [41]	✓							
Upham &Roberts (a) and (b) [8], [7]							✓	
Wallquist et al. [12]		✓						

ICQs are a special type of survey that was developed by [33] ([34], also referring to [35] and [36]). Their aim is to "collect informed public opinions of a population after respondents have been presented with a decision problem and have received expert information relevant to this problem (i.e., information about the consequences of specific policy options) [34]. Therefore, surveys and ICQs pursue different aims. In the studies under consideration here, however, the distinction is not always made, i.e. there are also standardized surveys with accompanying

information (e.g. [20, 24], or standardized surveys that test the impact of (certain types of) information (e.g.,.[16], [25]).

Six of the studies under consideration here used a mixed-method approach, i.e. combine qualitative and quantitative methods (cf. Table 3.1 and Table 0.1).

3.5 Target groups addressed

Studies on the public perception on CO_2 transport via pipeline target different groups of people, which can broadly be distinguished into four groups (cf. Table 3.2 and Table 0.1).

(1) professional stakeholders, i.e. people with a professional interest in CCS, including experts,
(2) local stakeholders, i.e. community representatives such as councilors,
(3) residents, i.e. people living near (potential) installations, and
(4) the general public, i.e. randomly selected individuals.

There may be differences within these categories: residents may be people owning the land that a pipeline is supposed to cross (e.g., [17]), people living in a community where the potential installation is to be sited (e.g., [37]), or people living in a region that may be affected (e.g., [25]). With regard to local stakeholders, [38] interview them but not with regard to a specific project, while [28] reports attitudes of local stakeholders in a community where a CCS installation was planned (Barendrecht, The Netherlands). So there are, in fact, varying degrees and dimensions of affectedness, which may have an impact on the attitudes of the target groups.

The vast majority of studies (16) target the general public. In each case 10 studies target professional stakeholders and residents, and three target local stakeholders (cf. Table 3.2 and Table 0.1).

Table 3.2: Target groups addressed in the studies with empirical evidence on the public perception of CO_2 pipelines

Study	Professional stakeholders	Local stakeholders	Residents	General public
Anderson et al. [17]	✓		✓	
Bradbury et al. [45]			✓	✓
Brunsting et al. [18]		✓		
De Best-Waldhober et al. [19]				✓
De Best-Waldhober et al. [39]				✓
De Best-Waldhober et al. [15]				✓
Dowd et al. [20]				✓
Duetschke et al. [16]				✓
Einsiedel et al. [14				✓
Gough et al. [11]			✓	
Ha-Duong et al. [37]	✓		✓	
Hund et al. [46]	✓		✓	
Johnsson et al. [21]	✓			
Kuijper et al. [28]		✓	✓	
Liang & Reiner [22]	✓			
Mabon et al. [38]	✓	✓		✓
Mander et al. [23]	✓		✓	
Oltra et al. [43]				✓
Palmgren et al. [10]				✓

Study	Professional stakeholders	Local stakeholders	Residents	General public
Riesch et al. [42]				✓
Roberts & Mander [44]			✓	
Schumann et al. [26]				✓
Schumann [25]				✓
Setiawan &Cuppen [27]	✓			
Shackley et al. [24]	✓			
Simpson & Ashworth [40]	✓		✓	
Ter Mors et al. [34]				✓
Terwel et al. [41]			✓	
Upham &Roberts (a) and (b) [8], [7]				✓
Wallquist et al. [12]				✓

4 RESULTS

In this section of the report, the evidence on public perception of CO_2 transport via pipelines will be presented and discussed. Information on countries and regions, target groups and nature of the evidence will be provided as applicable. As can be seen, the evidence is scattered and little systematic and empirical findings seem to be highly context dependent. However, in some studies predictors for the acceptance of CO_2 pipelines were identified which were supported by the findings of a review of 42 studies on CCS in general [9]. These predictors are explained in the end of this section (cf. Chapter 4.8).

4.1 Risk perceptions

Some studies are concerned with the general risk evaluation of the transport of CO_2 via pipeline. [39] report from their qualitative interviews among the general Dutch public that the issue of the safety of pipelines was raised by "several people". [40] report that in the case of a planned IGCC power plant with CCS in Queensland, Australia it was residents in particular who raised the issue of safety of transport and storage.

Some studies differentiate risk perceptions: [25], e.g., points out that in general, the personal risks associated with the capture, transport via pipeline and storage were assessed quite neutrally among the German public, but that the personal risk associated with storage was considered slightly higher than that of capture or transportation. In addition, the study shows that women had a more negative overall opinion of CCS than men, and they considered the risks to be higher for all three process steps.

With respect to professional qualification, [25] illustrates that among the general public in Germany people with higher professional qualification (university degree) evaluate the risk as less high than people with a lower professional qualification. It also finds regional differences and notes that along the Rhine (in the study the potential route of the pipeline) risk perceptions are higher than in Schleswig-Holstein, the proposed region of a CO_2 storage site.

From the point of view of the developer of the Barendrecht CCS project (The Netherlands), [28] reports that the perceived risks of local stakeholders and residents were higher than risks as calculated by experts, which the author partly attributes to socio-psychological mechanisms of risk perceptions, and partly to biased risk communication by "local politicians and opponents" as well as scientists "usually not with specific expertise in the area of external safety".

Other studies take the approach of ranking risks, mostly according to the three CCS components capture, transport and storage. [15] report that the majority of the Dutch general public evaluate both transport and storage negatively. In the particular case of Barendrecht, according to [41], the majority of "residents consider transport of CO_2 quite or very unsafe", a finding that apparently correlates highly with the negative evaluation of CO_2 storage. A higher evaluation of risks of storage than of risks of capture and transport are reported from Belgian, German and UK face-to face focus groups by [7, 8] as well as from Polish and Spanish online focus groups by [42].

A more detailed account provide [26] for the Northern German regions of North Frisia and Aurich and islands as well as for the German general public. They report that risks associated with transport were perceived lower than the risks associated with storage, and that in both cases personal risks were perceived lower than societal risks. Furthermore, they showed that the perceptions of the personal and societal risks of CO_2 transport via pipeline are the most important direct negative determinants of general attitudes towards CO_2 pipelines: the higher the perceived personal or societal risk, the more negative the general attitudes towards CO_2 pipelines.

[16] take a different approach and rank risk perceptions according to information provided and proposed type of storage, in their case saline aquifers, enhanced gas recovery and a depleted natural gas field. They find that mentioning pipelines has an effect on how the storage option is evaluated: storage in a depleted natural gas field is assessed less positively if a pipeline is mentioned and more positively if no transport option is mentioned, whereas storage in saline aquifers and a combination with enhanced gas recovery are always evaluated the same independent of the fact whether a pipeline is mentioned or not.

A ranking of risks associated more generally with CCS rather than of CCS components is presented by [21]. From a survey among professional stakeholders in the US they report the risk of CO_2 leakage from reservoirs was deemed higher than the risk from seismic activity and risks connected to transport and handling of CO_2.

Several studies provide evidence on the more specific safety risks of leakage: [43] in an anecdotic fashion from Spanish focus groups recruited from the general public and [44] from a UK citizen panel recruited from residents around a proposed CCS installation. [11] present more detailed evidence from focus groups of UK residents: "participants voiced concerns over whether long- and short-term health and safety could be guaranteed. Particular issues related to pipeline leaks, the speed and accuracy of detection and what steps are taken to both prevent leaks from happening and putting them right in the event that they do. Participants were also concerned about the local environmental impacts of a pipeline leak, for example on plants, wildlife and farm animals." They also report that prior to the provision of the respective information on properties of CO_2 and pipeline safety, concerns were voiced with regard to the risk of explosion. As a contrast to these lay perceptions, [24] found in a survey among professional stakeholders that they considered health and safety risks from leakages as minimal or non-existent.

Further specific perceived risks that are reported are damage due to seismic activity voiced by Indonesian professional stakeholders in semi-structured interviews [27] as well as by focus groups with residents in the UK [23]. UK residents also voiced the fear that CO_2 pipelines may become a terrorist target, although it was not considered a high risk [11]. [23] also report risks associated with the 'security' of the pipelines both by residents and by professional stakeholders. In addition, UK residents voiced the fear that pipelines might be damaged acci-

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dentally in the course of farm and construction work. Apparently the participants requested information on how the risk of third party damage could be minimized [11].

4.2 Benefit perceptions

With respect to benefit perceptions, [25] show for the German general public and for the public in the Rhine region and Schleswig-Holstein that the personal benefits of carbon storage and transportation via pipeline are generally considered lower than the personal benefits of capture. Moreover, the benefits of the capture step were considered much smaller by individuals with training at a post-secondary vocational school and individuals with a degree from a university than by individuals with no professional qualification or those with certified vocational training. Qualification-specific differences in appraisals of transportation and storage were not statistically significant.

For the Northern German regions of North Frisia and Aurich and islands as well as for the German general public [26] make clear that the perceptions of the personal and societal benefits of CCS are the most important direct positive determinants of general attitudes towards CO_2 pipelines: the higher the assessed personal or societal benefit of CCS, the more positive the general attitudes towards CO_2 transport via pipeline.

4.3 Economic issues

Economic issues connected to CO_2 transportation in pipelines can be distinguished into compensation issues for directly affected parties and the commercial status of CCS. Concerning compensation issues, [45] report from focus groups of residents in the US owning the properties in question that the participants “shared horror stories – for example, the story of a large company that laid a pipeline across someone’s pasture, but when increased temperatures from the pipelines severely limited both quantity and quality of forage in the alfalfa field, the rancher was unable to obtain compensation for his economic loss.” It is also reported from US residents [46] and French residents [37] that they raised the issue of the development of property value in the course of the construction of a CO_2 pipeline. Similarly, French local stakeholders discussed financial compensation for the city under consideration for a CCS installation with ample experience in natural gas pipelines [37]. Australian residents (land owners) were more concerned with land use issues during survey activities and after the laying of pipelines [17].

In terms of economic gains and losses, [21] report from a survey among professional stakeholders in the US that they “considered it urgent to build large-scale CCS plants (including transport and storage) in order to show that it is likely that the technology can reach commercial status.” From qualitative interviews with local stakeholders in a Scottish community with a history of oil and gas extraction but no concrete CCS installation planned, [38] report that future economic prospects do play a role in their perception of CCS and CO_2 pipelines. In Barendrecht, however, residents seem to have been little impressed with the economic prospects potentially raised by CCS deployment, as [28] reports: “For the Barendrecht project we (and others) have tried to emphasize the importance of a CO_2-infrastructure for the attractiveness of the Rijnmond region in the future. For energy intensive companies this may be a reason to invest in the area. The Barendrecht project includes an oversized pipeline that can be used in the future as part of a more extensive infrastructure. The pipeline will also enable an increase of the supply of CO_2 to the greenhouses in the region. Although these benefits are more concrete, short-term and closer to home than ‘climate change’ we still found that they were not very important for the direct neighbors of the project.”

4.4 Construction issues

A number of studies also report acceptance issues connected with the construction of CO_2 pipelines. [23] find that both UK residents and professional stakeholders generally view construction as a risk. In qualitative interviews among the Dutch general public, [39] find "that building the [CCS] infrastructure would be a hassle". [11] present a more detailed account from their UK focus groups of residents: "Short term disruption during the construction of the pipeline was a particular concern, in terms of both the duration and impacts of the construction process. While some voiced concern about the impacts of a pipeline, for example on local wildlife, historical sites and the rural landscape, and possible impacts on local businesses dependent on tourism, others were confident that things would be restored after the construction phase, although the potential impact on existing coastal erosion remained a concern. An increase in construction traffic was also identified as potentially exacerbating an existing problem given the small roads connecting local towns and villages."

4.5 CO_2 pipelines and natural gas pipelines

[7, 8], [10] and [12] introduce the aspect of comparing CO_2 pipelines to natural gas pipelines. It could be worth investigating in more detail how the reference to already existing natural gas pipelines influences the assessment of CO_2 pipelines. [7, 8] point out that German and UK focus groups in particular agreed that if natural gas could be transported and stored safely then so should be CO_2. [10] also report from the US general public that the impression prevailed that "[CO_2] pipelines were really not much different from natural gas pipelines." In a survey among the Swiss general public, [12] even found that respondents, having received relevant information, preferred a CO_2 pipeline over a natural gas pipeline in their vicinity. However, they also found that the most preferred option was not having a pipeline at all.

A related effect of place history can be observed in the studies of [38], [37] and [47], with no clear causal direction. The former two report the effects of a place history of oil and natural gas infrastructure. In both cases, there seems to be some familiarity with pipelines, and they are not perceived negatively from the outset. However, [11] report from UK residents with a place history of concentrated energy infrastructure that for them justice was an important factor of public acceptance: "participants continually questioned the benefits offered by CCS and locating it in their region. There was concern that it added to the existing concentration of power generation infrastructure (fossil fuel power stations and wind farms) that residents had to tolerate."

4.6 Information

As the evidence of the studies analyzed here suggests, information seems to be another important aspect of the public perception of CO_2 transport via pipeline. However, both the direction and the nature of the precise causal relationship are not yet fully understood. In a survey among the general public in Australia, the Netherlands and Japan, [20] find that information on transporting CO_2 has a positive effect on the overall evaluation of CCS. However, their findings contradict [16]'s (see above).

Still, in connection to CCS projects, there seems to be a certain demand of information on the transportation aspect. This is reported in a general fashion by [14] from a workshop with participants from the general public held in Canada as well as in a more detailed fashion by [40] for the ZeroGen CCS project in Queensland, Australia: "the CLG [Community liaison group; local stakeholders] group at Stanwell were very interested in learning more about the process involved in securing an easement for a pipeline, the construction of a pipeline, the safety of

transporting CO_2 via a pipeline and pipeline monitoring techniques once operational." In their case studies, [18] evaluate pipeline projects (in their case a natural gas pipeline defined as CO_2 pipeline analogue) negatively because the operators did not provide the information requested by the public.

4.7 Other aspects

In their survey among UK professional stakeholders [24] find that impacts of a CO_2 pipeline network on the landscape and the environment may be an issue of public acceptance. This finding is mirrored by [37]'s study of residents in a French city who were concerned with potential noise and the visual impact of such pipelines.

In addition, various other aspects were reported unsystematically throughout the studies. [11] mention that "the rationale for transporting CO_2 by pipeline and the CCS process in general" was questioned by some participants. From an ICQ among the Dutch general public, [15] report that participants considered "contribution to pollution due to coal mining", "increased price" and "new pipelines needed" as disadvantages of CCS in general. In an earlier study [19] they find, however, that the evaluation of the need for new pipelines seems to be somewhat dependent on the CO_2 source, testing very specific sources such as "Hydrogen production via coal gasification with CCS/Need for 10 new power plants with new pipelines" and "Hydrogen production via steam reforming with CCS/ Need for many new pipelines".

[11] also report that the issue of trust in project developers and pipeline operators was raised. Participants questioned the legal status of the UK grid operator National Grid and how it was related to external regulators. They were also skeptical vis-à-vis "profit making organizations emphasizing the wider environmental benefits of a project ahead of the financial benefits they would accrue."

From a survey among Chinese professional stakeholders, who were asked to rank three different CCS scenarios according to desirability, [22] report that the scenario with long-distance pipelines leading to inland onshore storage sites got the worst rating. The best rating received a scenario with "short distance CO_2 pipelines (<250km) connected to offshore CO_2 storage sites", with "inland CO_2 capture plants near storage sites with long distance transmission of electricity to the coast" in between. From the data presented, however, it cannot be concluded which impact (isolated or in combination with other factors) the pipelines really had on the overall assessment.

4.8 Predictors of acceptance for CO_2 pipelines

Previous studies on the acceptance of risks and technologies verified that the acceptance of technologies by the general public is greatly influenced by the intuitive perception of risks, as well as by the perception of benefits and trust [48-51]. In their review of 42 studies on public perception of CCS in general, [9] found out that many of the studies confirmed the finding that risk and benefit perceptions are two of the main predictors of the acceptance for CCS. In agreement with the literature on risk perception and technology acceptance, a number of studies analyzed by [9] showed that risk perceptions of CCS were a significant negative predictor of acceptance for CCS. For the acceptance of CO_2 pipelines this is confirmed by the study of [26] (cf. Chapter 4.1).

However, according to the studies reviewed by [9] the single best predictor for acceptance of CCS is the perception of benefits. The relation between benefit perceptions and CCS acceptance is positive: the higher the perceived benefits, the more positive the general attitudes towards CCS. [26] confirm this result for the acceptance of CO_2 pipelines (cf. Chapter 4.2).

For technology acceptance in general, trust is recognized as a key variable [48-51]. This is confirmed by the studies on public perception of CCS, reviewed by [9]. Trust can have direct positive effects on acceptance or mediated effects through perceived risks or benefit perceptions [9]. To the best of our knowledge, the influence of trust on the acceptance of CO_2 pipelines has not yet been systematically tested. However, because [11] showed that their results on public perception of CO_2 transportation in pipelines are consistent with previous findings on CCS acceptance, it can be assumed that trust is an important predictor as well for the acceptance of CO_2 pipelines.

5 CONCLUSIONS

Public perception of CO_2 transportation in pipelines has been investigated for roughly a decade. However, the majority of the 30 studies reviewed here contains empirical evidence on public perception of CO_2 pipelines which is scattered and little systematic. This means that for factors such as economic and construction issues, familiarity with natural gas pipelines, the physical or visual impact of CO_2 pipelines or the role of information no general conclusions on the existence, nature and direction of causal relationships between these factors and the acceptance of CO_2 pipelines can be derived.

In contrast, risk perceptions, benefit perceptions and trust were identified as factors which have the same systematic correlations with the public perception of CO_2 pipelines, CCS in general as well as with technology acceptance in general: risk perceptions are negatively correlated with public perception, whereas benefit perceptions and trust are positively correlated. Therefore, it can be concluded that risk perceptions, benefit perceptions and trust will also be the most important influencing factors of the public perception of the pilot cases defined in GATEWAY.

With regard to risk perceptions, studies on public perception of CCS have shown that CO_2 is often perceived by lay persons as unhealthy or poisonous [26, 52]. Therefore, the most frequently concern regarding CO_2 storage and transportation voiced by lay persons is that CO_2 might leak back into the atmosphere [9, 26]. It can be assumed that the risk of CO_2 leakage will also be raised by the public concerned by the GATEWAY pilot cases. Hence, positive public perception of the pilot cases is more likely if communication strategies are developed and applied which clearly describe possible risks and impacts on people and the environment and how the projects promoters will deal with them. However, one should be aware that even if risk communication [cf. e.g. 53] is applied public acceptance of an infrastructure project cannot be guaranteed. Furthermore, the effectiveness of risk communication might be very limited in regions in which CCS is already perceived among the public as risk technology [26].

Benefit perceptions are the most important positive determinant of public perception of CO_2 pipelines and CCS in general. It can be assumed that projects by which the public affected feels to carry only the burden of the project whereas others would have the benefits will be hardly accepted. Therefore, positive public perception of GATEWAY pilot cases is more likely if they have benefits for the affected regions, municipalities, citizens which at least compensate the costs. Additionally, positive perception is more likely if the benefits of the projects will be communicated properly to the concerned parties.

Trust is a key variable for technology acceptance in general, CCS in general and will also be crucial for the public perception of the GATEWAY pilot cases. It can be assumed that the benefit perceptions of the pilot cases will be more positive and risk perceptions less negative if the persons responsible for the CO_2 infrastructure projects are trusted by the parties affect-

ed. However, from research on CCS perception it is known that industry is one of the least trusted stakeholders [9]. Government organizations are perceived a bit more trustworthy but are often not trusted to manage CCS operations safely [9]. The most trusted stakeholders are researchers and non-governmental organizations (NGOs) [47, 54]. Generally, trust in the persons responsible for the pilot cases can be enhanced through fair procedures regarding the siting of the CO_2 pipelines, honest communication and collaboration of multiple stakeholders [9].

However, even if strategies for diminishing risk perceptions and enhancing benefit perceptions and trust increase the likelihood of positive perception of a GATEWAY pilot case, its acceptance among the affected public will be still uncertain. This is due to the fact that our review has also shown that public perception of CO_2 pipelines is highly context-dependent and influenced by several factors such as economic and construction issues, familiarity with natural gas pipelines, the physical or visual impact of CO_2 pipelines or information. Therefore, a reliable assessment of public perception of a specific CO_2 infrastructure project can only be done by carrying out empirical social research regarding the specific project, i.e. performing surveys, ICQs, interviews or mini-publics in order to explore the perceptions of those parts of the public which will be affected by the project. Accordingly, empirical social research on the public perception should be an integral part of the PCI feasibility study which will be proposed by the GATEWAY project.

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APPENDIX

Table 0.1: Overview of the studies

Study	Year	Country	Focus of research	Qualitative Method	Quantitive Method	Target groups
Anderson et al.: “Exploring CCS community acceptance and public participation from a human and social capital perspective” [17]	2012	AU	Procedures and communication	Semi-structured interviews		Professional stakeholders, residents
Bradbury et al.: “The Role of Social Factors in Shaping Public Perceptions of CCS: Results of Multi-State Focus Group Interviews in the US” [45]	2009	US	Attitudes, knowledge and the impact of information	Interviews, standardized mini-publics	Standardized survey	Residents, general public
Brunstig et al.: "The Public and CCS: the Importance of Communication and Participation in the Context of Local Realities." [18]	2011	DE, NL, UK, ES	Procedures and communication	Case studies		Local stakeholders
De Best-Waldhober et al.: “Informed and uninformed public opinions on CO_2 capture and storage technologies in the Netherlands” [19]	2009	NL	Attitudes, knowledge and the impact of information		Standardized survey, Information-Choice Questionnaire	General public
De Best-Waldhober et al.: “Awareness, knowledge, beliefs, and opinions regarding CCS of the Dutch general public before and after information” [39]	2011	NL	Attitudes, knowledge and the impact of information	Interviews	Standardized survey, Information-Choice Questionnaire	General public
De Best-Waldhober et al.: “Informed public opinion in the Netherlands: Evaluation of CO_2capture and storage technologies in comparison with other CO_2 mitigation options” [15]	2012	NL	Attitudes, knowledge and the impact of information		Information-Choice Questionnaire	General public

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Study	Year	Country	Focus of research	Qualitative Method	Quantitive Method	Target groups
Dowd et al.: "Investigating the link between knowledge and perception of CO_2 and CCS" [20]	2014	AU, NL, JP	Attitudes, knowledge and the impact of information		Standardized survey with information	General public
Duetschke et al.: "Does it Make a Difference to the Public Where CO_2 Comes from and Where it is Stored?: An Experimental Approach to Enhance Understanding of CCS Perceptions" [16]	2014	DE	Attitudes, knowledge and the impact of information		Standardized survey with information	General public
Einsiedel et al.: "Assessing socio-technical mindsets: Public deliberations on carbon capture and storage in the context of energy sources and climate change" [14]	2013	CA	Attitudes, knowledge and the impact of information	Not standardized mini-publics		General public
Gough et al.: "Public perceptions of CO_2transportation in pipelines" [11]	2014	UK	Attitudes, knowledge and the impact of information	Standardized mini-publics		Residents
Ha-Duong et al.: "Social aspects of Total's Lacq CO_2 capture, transport and storage pilot project" [37]	2011	FR	Procedures and communication	Case study		Professional stakeholders, residents
Hund & Greenberg: "Dual-track CCS stakeholder engagement: Lessons learned from FutureGen in Illinois" [46]	2011	US	Attitudes, knowledge and the impact of information	Interviews, standardized and not standardized mini-publics		Professional stakeholders, residents
Johnsson et al.: "Stakeholder attitudes on Carbon Capture and Storage-An international comparison" [21]	2010	AMN, JP, EU	Attitudes, knowledge and the impact of information		Standardized survey	Professional stakeholders

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Study	Year	Country	Focus of research	Qualitative Method	Quantitive Method	Target groups
Kuijper et al.: "Public Acceptance Challenges for Onshore CO_2Storage in Barendrecht" [28]	2011	NL	Procedures and communication	Case study		Local stakeholders, residents
Liang & Reiner: "The Evolution of Stakeholder Perceptions of Deploying CCS Technologies in China: Survey results from three stakeholder consultations in 2006, 2009 and 2012" [22]	2013	CN	Attitudes, knowledge and the impact of information	Interviews	Standardized survey	Professional stakeholders
Mabon et al.: "Perceptions of sub-seabed carbon dioxide storage in Scotland and implications for policy: A qualitative study" [38]	2014	UK	Attitudes, knowledge and the impact of information	Interviews		Professional stakeholders, local stakeholders, general public
Mander et al.: "Risk from CO_2 storage in saline aquifers: a comparison of lay and expert perceptions of risk" [23]	2011	UK	Attitudes, knowledge and the impact of information	Standardized mini-publics	Standardized survey	Professional stakeholders, residents
Oltra et al.: "Lay perceptions of carbon capture and storage technology" [43]	2010	ES	Attitudes, knowledge and the impact of information	Standardized mini-publics		General public
Palmgren et al.: "Initial public perceptions of deep geological and oceanic disposal of carbon dioxide" [10]	2004	US	Attitudes, knowledge and the impact of information	Semi-structured interviews	Standardized survey, standardized survey with information	General public
Riesch et al.: "Internet-based public debate of CCS: Lessons from online focus groups in Poland and Spain" [42]	2013	PL, ES	Research-related methodological questions	Standardized mini-publics		General public

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Study	Year	Country	Focus of research	Qualitative Method	Quantitive Method	Target groups
Roberts & Mander: “Assessing public perceptions of CCS: Benefits, challenges and methods” [44]	2011	UK	Research-related methodological questions; Attitudes, knowledge and the impact of information	Standardized mini-publics		Residents
Schumann et al.: “Public Perception of CO_2 Offshore Storage in Germany: Regional Differences and Determinants” [26]	2014	DE	Attitudes, knowledge and the impact of information		Standardized survey	General public
Schumann: “Public Acceptance” [25]	2015	DE	Attitudes, knowledge and the impact of information		Standardized survey with information	General public
Setiawan & Cuppen: “Stakeholder perspectives on carbon capture and storage in Indonesia” [27]	2013	ID	Attitudes, knowledge and the impact of information	Semi-structured interviews		Professional stakeholders
Shackley et al.: “ Stakeholder perceptions Of CO_2 capture and storage in Europe: Results from a survey” [24]	2007	23 European countries	Attitudes, knowledge and the impact of information		Standardized survey with information	Professional stakeholders
Simpson & Ashworth: “ZeroGen new generation power - a framework for engaging stakeholders” [40]	2009	AU	Procedures and communication	Case study, not standardized mini-publics		Professional stakeholders, residents

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Study	Year	Country	Focus of research	Qualitative Method	Quantitive Method	Target groups
Ter Mors et al.: "A comparison of techniques used to collect informed public opinions about CCS: Opinion quality after focus group discussions versus information-choice questionnaires" [34]	2013	DE, GR, NL, NO, RO, UK	Procedures and communication	Standardized mini-publics	Information-Choice Questionnaire	General public
Terwel et al.: "It's not only about safety: Beliefs and attitudes of 811 local residents regarding a CCS project in Barendrecht" [41]	2013	NL	Attitudes, knowledge and the impact of information		Standardized survey	Residents
(a) Upham & Roberts: "Public perceptions of CCS in context: results of NearCO(2) focus groups in the UK, Belgium, the Netherlands, Germany, Spain and Poland" [8] (b) Upham & Roberts: "Public perceptions of CCS: Emergent themes in pan-European focus groups and implications for communications" [7]	2011	UK, BE, NL, DE, ES, PL	Attitudes, knowledge and the impact of information		Standardized mini-publics	General public
Wallquist et al.: "Public acceptance of CCS system elements: A conjoint measurement" [12]	2012	CH	Attitudes, knowledge and the impact of information		Standardized survey with information	General public

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Table 0.2: Country codes

Country code	Country/Region
AMN	North America
AU	Australia
BE	Belgium
CA	Canada
CH	Swiss
CN	China
DE	Germany
ES	Spain
EU	Europe
FR	France
GR	Greece
ID	Indonesia
JP	Japan
NL	The Netherlands
NO	Norway
PL	Poland
RO	Romania
UK	United Kingdom
US	USA