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Anticipating the social fit of CCS projects by looking at place factors

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ABSTRACT

Understanding the factors influencing the acceptance of carbon capture and storage (CCS) projects is key for the projects' deployment and for accelerating the global mitigation of CO_2 emissions. While anticipating the ways in which "places" can potentially affect a technology's deployment is relevant to mitigating social risks, social aspects are often omitted or included late in site selection processes. Here, we present a methodology to include place factors upstream in the site-screening process based on a literature review of former CCS implementation processes and maps of potential locations. We identified the place factors that had been determinative for the acceptance of or opposition to 38 CCS projects. Then, the usability of geographic information system (GIS) maps to represent social factors around potential storage sites in Switzerland was assessed. Our results show that place factors have positively influenced 22 and negatively impacted 16 projects in the past. In addition, it is possible to visualize several factors around potential CO_2 storage locations, while unmappable factors must be explored at later stages. We conclude that awareness of place factors coupled with reflection on the values pushed by the technology will likely enable better site choices.

1. Introduction

Carbon capture and storage (CCS) is considered one of the key technologies for stabilizing or reducing greenhouse gas emissions to below the 1.5 or 2 °C target established in the Paris Agreement (IPCC, 2005). While up to July 2021, 49 facilities of CO_2 storage have been completed around the globe (Global CCS Institute, 2021), the pace of deployment of the technology has been much slower than expected. Thus, there is a clear disconnect between the envisaged role that policymakers have had of CO_2 storage and its real implementation (Reiner, 2016). The reasons for the delay in deployment are complex and diverse. The negative response from local communities is one of the main barriers to the evolution of projects in Europe (Patel and Henriksen, 2017). Negative public responses have led to project cancelations in Poland, Germany, and the Netherlands (Feenstra, Mikunda, and Brunsting, 2010; Karohs, 2013; Kaiser, Zimmer, Brunsting, Mastop, and Pol, 2014). Furthermore, political opposition and the minimized role of CCS in the German climate agenda (BMUB, 2016; Vögele et al., 2018), as well as banning onshore CO_2 storage in the Netherlands (Cuppen et al., 2015), have hampered the development of CCS in Europe.

A central decision in the life of a CCS project is where to situate it. The choice of a storage site is contingent on geological factors, which determine the long-term containment of CO_2 and the level of risk for the community and nature. Furthermore, the appropriateness of a site choice will depend on whether the residents and local authorities agree with the siting process, according—at least partially—to their perception of fairness and trust in decision making (Wüstenhagen et al., 2007). In jurisdictions where local authorities or residents can oppose such siting choices, neglecting this is likely to stop projects. While both the technical and social aspects are determinative of a project's advancement, the dominant criteria employed in the siting decision are asymmetrical: the geologic and economic criteria form the basis of the selection, while the social characteristics and concerns are often completely excluded or included superficially or late in the process (Ashworth et al., 2012). This might be connected to the low salience of early and substantive engagement among CCS experts who do not undertake engagement processes (Xenias and Whitmarsh, 2018).

Bringing in social criteria at a late stage is problematic because it ignores the risks associated with the social fit of the project in a particular context (see Meyer et al., 2008). The reasons for opposing CCS projects vary strongly across locations and depend on specific issues linked to the demographics of a community; some examples are questions of environmental justice in poorer areas (Bradbury, 2012) or interference with existing economic activities or development plans—for instance, developing tourism (Dütschke, 2011). This causes a loss of effort and time resources for people and project developers and

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can be detrimental to the industry. For this reason, consideration of the social context in relation to site selection and project design and implementation is a critical factor for achieving host community support (Ashworth et al., 2012).

Nonetheless, assessing the social fit in a direct way (namely by polling, direct interventions, or surveying the population) is hardly possible at the very early stages of projects when several locations are being screened. In those phases, analyzing the social fit of the project to specific contexts is too resource-intensive, as it requires understanding how the particular characteristics of a location and its inhabitants might affect the likelihood of public support for a CO_2 storage project. In addition, it can be awkward for people to express their emotions and opinions, as experts—who usually frame their contributions in a scientific and rationalist way—dominate the discourse (Roeser and Pesch, 2016). There might be large uncertainties about the project design, and these may lead to not involving stakeholders' concerns in a timely manner or providing information that is not completely accurate and credible (Pragnell, 2013). Discourses carried by the media can shape too early how innovation processes are construed and discussed by the publics by framing the type of arguments that are accepted as valid (Røyrvik et al., 2012). Interpretation of such media discourses will connect with narratives about previous projects circulating within communities and can be mobilized as argumentative resources by project opponents to initiate or fuel controversies (Cuppen et al., 2020). Additionally, given that only a few sites will be ultimately considered, communicating to numerous potential communities might be an unnecessary burden both for project developers and locals (for example, see the site screenings conducted by Finley, Gustison, Lim, & Chang, 2003; Ramírez et al., 2008; Strachan et al., 2011). The effect might be a lack of interest from diverse publics, who may see no real concern in the implementation of the project, as it is too abstract and distant in time.

In other fields, such as research on ecosystem services, these types of issues are addressed by systematically evaluating place factors (de Groot, Wilson, and Boumans, 2002) and using maps to visualize, anticipate, and reflect on this information (Troy and Wilson, 2006). The few existing tools in the CCS literature to include social factors are based on lists that lack an organized structure established on evidence-based factors (see Ashworth et al., 2011; Wade and Greenberg, 2011; Brunsting et al., 2015; Haug and Stigson, 2016). Indeed, much of the information on the social factors that influence the success of CCS projects appears scattered throughout academic literature and organization reports (Hammond and Shackley, 2010; Bradbury, 2012; Oltra et al., 2012; Pragnell, 2013; Inderberg and Wettestad, 2015; Lockwood, 2017). On the other hand, the maps used in the siting processes of CCS integrate technical or environmental information, but they hardly ever assess social criteria (for instance, see Ramírez et al., 2008; Li, Liu, Liu, and Li, 2013; Alcalde et al., 2018).

The aim of the current paper is to contribute to the development of such upstream tools to conduct social screening for sites on a large scale based on existing evidence and maps. We propose to integrate the concept of place within these tools, as it enables us to grasp the connection between the physical and social factors in a given location. We argue that these tools can broaden CCS experts' and project developers' understanding of the potential social responses to the projects they propose. This could lead to a better social fit of the projects, potentially reducing delays and cancelations and thus speeding up the CCS technologies needed for meeting the Paris Agreement targets. In this context, the questions we attempt to answer in this research are: (1) "Which place factors have been highlighted in successful and unsuccessful CCS projects, and what is the meaning they had in the process?" and (2) "How can maps display the identified place factors?". Taking recent discussions about the potential siting of CCS facilities in Switzerland as a starting point, we develop a GIS map of place factors at the Swiss national scale and indicate how it can foster reflection during a screening process.

2. Integrating social concerns in project siting and implementation

2.1. Acceptance of CCS

The notion of acceptance refers to public reactions ranging from active support to a lack of opposition to projects or a technology (Wüstenhagen et al., 2007). In this paper, we focus on community acceptance of siting decisions by local stakeholders, particularly residents and local authorities. As underlined by Oltra et al. (2012), acceptance is understood as a collective response that is made of various interacting social and psychological processes influenced by a range of wider contextual factors.

Social acceptance depends on attitudes toward the technology, which in turn are influenced by, for instance, the concern about climate change (Shackley et al., 2004) or the frame in which CCS is presented—as a "techno-fix" (business as usual) solution or as part of a systemic approach to climate change mitigation (Whitmarsh et al., 2019). The relationship between industry representatives and the community is dynamic throughout the project phases and exists on a continuum from opposition to tolerance and support (Hall et al., 2015; Vargas-Payera et al., 2020).

The issues of "place" and "process" are central when it comes to understanding how people respond to the proposed projects at a local level (Peterson, Stephens, and Wilson, 2015; Jones, Olfe-Kräutlein, Naims, and Armstrong, 2017). The "process" refers to the ways in which the publics are engaged with the development and siting decisions. The responses of the communities in this regard are shaped by elements such as trust and their perception of distributional and procedural justice—namely, whether different sections of the community believe in the information and intentions of the investors and experts, the process gives all relevant stakeholders an opportunity to participate, and the costs and benefits are perceived to be fairly distributed (Wüstenhagen et al., 2007). The "place" refers to the location of the project. A project is perceived differently in different locations depending on the characteristics and beliefs of the population and the features of the place and related benefits and risks (Krause et al., 2014; Petrova, 2016).

Social research has predominantly focused on what is developed (general acceptance) and how it is deployed (procedural matters). The "where" has been included in the notion of "sites" to be developed or "backyards" replete with opponents, both of which are problematic (Devine-Wright, 2011). In response to these interpretations, concepts such as social fit (Hammond and Shackley, 2010), place-technology fit (McLachlan, 2009; Devine-Wright and Wiersma, 2020) and emplacement (literally putting something into place) (Cresswell, 2004) have been referred to as a more preferable means of representing the context of technology deployment.

2.2. Social site characterization and responsible research and innovation

The core approach developed in the CCS sector to take into account locational aspects is social site characterization. The term has been coined to describe the process of obtaining a solid understanding of the concerns and perspectives of a project's stakeholders and incorporating them into the design and implementation of the project (Wade and Greenberg, 2011). According to Brunsting et al. (2015), this can be done by identifying the local social circumstances and the factors shaping public opinion to design strategies of public engagement that approach the public with the appropriate type of information. Another purpose of social site characterization is to involve all relevant stakeholders and initiate discussions in which the public feels listened to and empowered.

While social site characterization is an important tool for exploring the context of locations, it is mostly intended for downstream application—namely, once sites have been selected (e.g., Wade and Greenberg, 2011). As we explained in the introduction, tools tailored for integrating social and location-related aspects upstream in the siting process are important to anticipate and reflect upon potential social concerns in particular locations.

Such an endeavor is in line with recent efforts to promote "responsible research and innovation" (RRI) to give a more prominent role to ethical and social considerations in research and innovation (Cuppen, van de Grift, and Pesch, 2019). The RRI approach focuses on the contribution that technological development can make to society and calls for a deliberative approach to evaluate this contribution (Owen et al., 2012). RRI thus implies discussing values that relate to a technological innovation and its effects (Correljé et al., 2015; Cuppen et al., 2019). Owen, Macnaghten, and Stilgoe (2012) also underlined that this aspect gives RRI a clear normative dimension.

Some studies have mentioned the relevance of the RRI approach in relation to CCS development (Mabon, and Shackley, 2013; Parkhill, Pidgeon, Corner, and Vaughan, 2013), but no tailored tools have yet been developed in the context of siting decisions. Focusing more specifically on biomass energy with carbon capture and storage (BECSS), Gough, Mabon, and Mander (2018, p. 255) stated that "there is clearly a compelling case for establishing responsible governance frameworks, within the principles of responsible research and innovation (RRI) for negative emissions approaches." The RRI approach calls for an anticipation of the social consequences of projects, which should already start in "very upstream" phases (see Owen, Macnaghten, & Stilgoe, 2012). As such, RRI is a useful concept that complements social site characterization and explores possibilities to take site characteristics into account early on.

2.3. *Learning from land use planning: How to address place factors at an early stage*

The concept of place, developed by human geographers in the late 1970s, offers a way to appreciate the interaction between the physical and social aspects of locations. Place theories define the concept as a location that comprises a physical setting, the human activities that occur there, and the psychological processes, namely meanings and attachments, rooted in the setting (Cresswell, 2004; Tuan, 1977).

Places are characterized by three interrelated dimensions: location, locale, and sense of place (Agnew, 1987). Location corresponds to the coordinates that situate a place on a map or its situation relative to other places. Locale refers to the physical elements that can be found in a place, which can be natural (for instance, a mountain, a river, or a forest) or human-made (buildings, roads, or even crowds). Last, sense of place refers to the way people relate to a place, including the meanings, affects, and attachments they ascribe to it. These three dimensions are interrelated, and any change in one of them might affect the others. Disruption to a place by an external event, such as the decision of an operator to install a CCS facility, is thus likely to trigger positive or negative reactions in people, as they are emotionally bound to that place.

Thinking in terms of place emphasizes the constant interplay between the physical features and the social relationships going on in given locations. Thinking about the siting of a CCS project in terms of place implies considering how the technology might trigger reactions based on the sense of place and taking into account that people might not react to the technology per se but to how the technology impacts their "locale." In this paper, we refer to the features of a place that mediate the reactions of publics with respect to a project's implementation as place factors. A key challenge here is to find ways to integrate such thinking about place into project development.

Researchers in planning, protected areas management, and related fields have developed tools to integrate the notion of place in spatial planning decisions, including the emotional bonds and concerns that people have toward places. Spatial development managers require that special places, defined as places to which people have some form of attachment, be spatially identified, along with the reasons for their importance (Brown, 2004). This can be achieved by, for instance, suitability analyses, which identify and narrow the range of potential areas that are suitable for a specified land use based on a predefined set of decision criteria (Brown, 2004). Participatory or survey-based methods to assess landscape values can help evaluate different planning alternatives according to aspects of human use, interests, and emotional connections (Reed and Brown, 2003). Landscape values are values people associate with particular places (e.g., aesthetic, cultural, or wilderness values) and can provide a reasonable proxy for measuring place attachment (Brown and Raymond, 2007).

It is possible to map some concerns and proxies of place attachment using GISs. Such tools help to integrate landscape values into spatial planning decisions and allocations. The GIS has sparked the interest of policymakers for three main reasons: first, most information used in policymaking contains a spatial component; second, extending the use of spatial information to all relevant stakeholders presumably leads to better policymaking; and third, this policy-related information can be analyzed and visualized spatially, and the resulting maps can persuasively convey ideas (Sieber, 2006).

However, the inclusion of landscape values in GIS has been criticized for its oversimplification of social processes and its positivist approach. GIS models tend to reduce complex societal processes to points, lines, areas, and attributes (Sheppard, 1995; Sieber, 2006) ignoring that the potential number of physical (natural, architectural, cultural, or urban) features that may affect attachment is virtually infinite (Farnum et al., 2005; Lewicka, 2011). Alternative approaches to GISs, such as critical or participatory GISs, try to overcome such limitations either by reflecting on the possible effects of maps or by integrating the perspective of those who have a stake in the objects mapped (Schuurman, 2000; Weiner et al., 2002). Users should see maps as a first step in gaining an overview of locations and not a replacement of the locals' knowledge. Users should reflect on the uses of map data and the values that are being prioritized with their choices. In the following sections, we propose an approach to integrate place factors into a GIS tool that can be used reflectively during the siting process of carbon capture and/or storage facilities.

3. Methods

We developed an approach to integrate place factors in the siting process of CO_2 storage projects by first empirically identifying relevant place factors for CCS acceptance through a literature review of CCS projects. We subsequently mapped the respective proxies of these factors in a GIS model using the case of Switzerland as an example. The methodology followed in this paper is outlined in Fig. 1. Flowchart of the methodology used.

3.1. *Background of CCS in Switzerland*

We explored the use of maps for representing place factors using the case of Switzerland as an illustration. The Swiss Federal Council has committed to reducing greenhouse gas emissions by 50% compared to 1990 by 2030 and by 100% by 2050 (Federal Council, 2019, 2015). In 2018, domestic emissions were only 14.3% below the base year emissions of 1990 (FOEN, 2020b). Therefore, a tight carbon budget and the need to compensate for a lack of substantive short-term reductions will likely require Switzerland to develop and implement additional CO_2 mitigation policies and achieve negative emissions. This, in turn, will require Switzerland to develop additional CO_2 mitigation policies, such as promoting CCS. Public decision-making in Switzerland is strongly influenced by the system of direct democracy, which enables voters to oppose some decisions through a referendum. A referendum can be held at the local or national level (Kriesi and Trechsel, 2008). Furthermore, several mechanisms enable residents or non-governmental organizations to appeal against infrastructure projects (Ladner, 2010). Thus, it is likely that the local population or key stakeholders will have a say at various points in the process. This will lead to discussions that must be

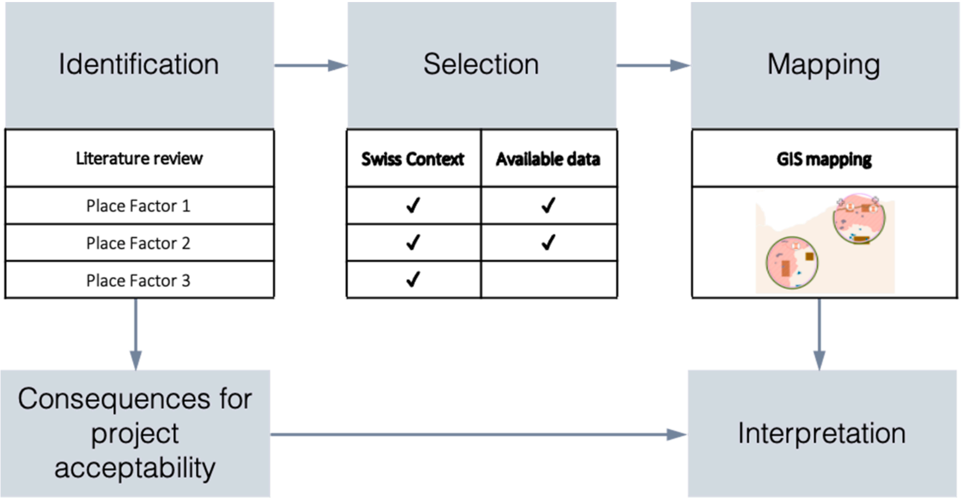

Fig. 1. Flowchart of the methodology used.

informed by considerations such as those discussed here.

It is not yet clear whether CO_2 will be stored in the Swiss underground. Geological studies conducted so far suggest that Swiss subsurface locations have a moderate capacity for storage (Chevalier et al., 2010). These locations represent a short-lived solution for dealing with the quantity of emissions of proximal large-scale CO_2 point sources. Therefore, the export of CO_2 to a location with greater capacity, such as the Nordic Seas, is a likely scenario currently explored by the Swiss Federal Office for the Environment (FOEN, 2020a). Nonetheless, the Swiss subsurface is largely unexplored, and the prospect of local storage has not been ruled out FOEN, 2020b. Independently of these scenarios, we use Switzerland for the exemplification of our concept.

3.2. Literature review

We conducted a literature review in November 2019 on the factors that determine the social success or failure of capture and/or storage projects around the world. We searched for reports on Google and scientific articles on Google Scholar. We chose Google Scholar over other databases to increase the coverage of social science sources and include theses, book chapters, and reports from research projects (Martín-Martín et al., 2018). We used different combinations of the following terms: “carbon storage,” “place,” “site,” “selection,” “characterisation,” “screening,” “social,” “acceptance,” and “acceptability.” We filtered and chose documents with empirical information on how aspects of the project or its host community had contributed to the public’s response. Based on the sources found, we used backward and forward snowballing to identify more publications. In the end, documents about 38 projects were considered to be relevant.

First, we determined whether the project was overall perceived as positive or negative by the local community. We identified the location characteristics that researchers described as contributing to the outcome and the benefits and concerns raised by the publics in relation to the project. We then manually coded and cross-checked each document. The characteristics of the location were classified into the following categories: “location characteristics,” “social, economic, and legal aspects,” and “perceptions and experiences.” Next, we classified the presence of each factor as a dichotomous variable and included it in the dataset when at least one document mentioned it as relevant for the acceptance or opposition of a project. Some projects were coded more than once when the proposed technology or location changed. Different authors mentioned or highlighted different characteristics, yet we did not find authors contesting the relevance of factors considered important by others. As expected, the presence of certain characteristics in a place sometimes overlapped with benefits or concerns that the potential project induced in the community.

3.3. GIS mapping of place factors

We first identified the place factors that were context-relevant for Switzerland. We considered former sites of oil and/or gas exploration or exploitation as potential carbon storage sites. These sites were drilled to explore domestic fossil fuel resources without economic success (Leu, 2012) and usually correspond to locations where geological studies have been conducted—therefore, they provide a higher availability of data. In reality, saline aquifers are also considered as potential storage sites, and a whole range of geological and technical criteria are employed for site selection.

We obtained the geographic datasets (hereon called indicators) for the criteria generated in the literature review for a national spatial scale. The production of the maps was processed in ArcGIS Pro using the Swiss coordinate system LV 95 (Swisstopo, n.d.). We conducted an overlay analysis to observe which place factors are present around the potential CO_2 storage points. This analysis allowed us to combine input layers to determine the composite map layer (ESRI, 2016). For this proof of concept, we used a buffer distance of 3 km around the points. Kienast, Degenhardt, Weilenmann, Wäger, and Buchecker (2012) reported that this distance contains a large variation of the preferred landscape properties for the nearby recreation of Swiss people. We mapped the different place factors within the drawn buffers, opting for a resolution of 100 m × 100 m cell size to capture information on the landscape. We dissolved the feature attributes and intersected them with the buffers. Finally, we extracted the statistics of the individual buffers, normalized the values, and visualized them using the STARS package (Pebesma et al., 2019) within the R 3.6.1 software (R Core Team, 2019).

4. Results: Reported place factors of former CCS projects

In this section, we introduce the results of the literature review, identifying the place factors that played a role in the acceptance of CCS facilities. Then, we indicate how these factors were converted into mappable indicators and present the results of the mapping exercise.

The social fit of the projects was mentioned as relevant in 38 projects, 18 of which were supported by the public, 15 rejected, and 5 not formally proposed. Other projects were canceled for reasons other than public acceptance or have been developed successfully but did not publish information on the social considerations of the siting process. Since social fit refers to the compatibility between projects and the local context, both the type of facility and place factors determined the match.

The type of facilities and their framing (see Fig. 2) determine and

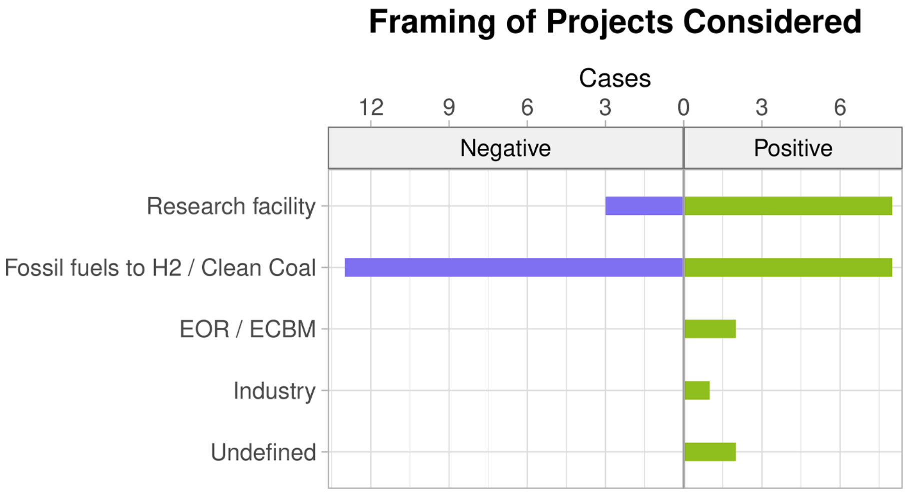

Fig. 2. Projects considered in this study with their respective framing.

provide visibility to the benefits that projects offer to the communities. Benefits linked to innovation, economic benefits derived from the fossil fuel industry, or the decreased environmental impact of industries were relevant for the communities' perception of the project. Concerns linked to the safety of operations, the place of origin of the gas, and the delay in the energy transition affected the acceptance of projects.

As shown in Fig. 3, aspects of the location, the socio-economic characteristics, and the perceptions and experiences of communities were mentioned as relevant for the social fit of different projects. We suggest that the reader use Fig. 3 as a guide for the following section.

4.1. *Location place factors*

4.1.1. *Offshore sites*

In the cases analyzed, six offshore cases were accepted or would have been potentially accepted by the population, and one was opposed. The projects with offshore storage avoided some concerns, such as the effects on property pricing and risks to human health; therefore, they had a smaller risk of opposition (Lofstedt, 2015). By contrast, the small demonstration project in Kona, Hawaii encountered public opposition, as people "feel very passionately about their waters"; the population saw no benefits derived from the project and felt that outsiders (researchers from Norway and Japan) were trying to sell an experiment to the community (de Figuereido, 2003). In the Yubari project in Japan, the project managers assumed that the public would accept an onshore enhanced coalbed methane project rather than an offshore project that would pose risks to marine ecosystems (Markusson et al., 2011). Independently of the support for the project, the communities raised concerns about the effects on the fishing industry and marine biodiversity.

4.1.2. *Industrial sites*

All analyzed projects that were accepted by the public and implemented on an industrial site were close to coal mining areas or areas with an existing power plant or oil or gas extraction, processing, or storage activities. For instance, the project Rotterdam Opslag en Afvang Demonstratieproject (ROAD), developed in the port of Rotterdam and implemented in an industrial area of Maasvlakte, encountered little opposition. As this is a cluster of industrial activity, nobody lives in these areas and many of the people living close by work in the industries (Reiner, Riesch, and Chyong, 2011).

In the municipality of Porsgrunn, Norway, a potential CCS project linked to the cement and ammonia industry with offshore storage seemed to be valued by the population. The city is located near the coast and has a long history of industrial development. The population seemed to appreciate the efforts that the industry made for reducing CO_2 emissions, including CCS, and saw the project as an opportunity to tackle environmental issues (Haug and Stigson, 2016)).

In contrast, the projects White Rose in the UK, Greenville in Ohio, and Carson in California were also proposed in industrial sites but faced opposition for diverse reasons, as will be explained in the following sections.

4.1.3. *Areas of fossil fuel extraction, processing, and/or storage*

The projects Peterhead, Longannet, and Don Valley in the UK, Lacq in France, Tomakomai and Yubari in Japan, and some projects in the US Midwest were proposed in regions with a tradition of coal mining or oil extraction and/or an associated power plant. These regions have institutions that are familiar with the risks; they see the project as an opportunity to continue using the existing infrastructure and need the jobs (Hammond and Shackley, 2010; Ha-Duong, Gaultier, and Deguillebon, 2011; Markusson et al., 2011; Reiner et al., 2011; Lockwood, 2017; Mabon, Shackley, and Bower-Bir, 2014). Many of these locations share the fact that after decades of economic prosperity, development plans have to be reinvented or a future for the fossil fuel industry has to be found, making CCS look like a promising option.

Fossil fuel power stations were not welcome in areas that lacked familiarity with the industry or disagreed with extending the fossil fuel industry. For instance, the residents of Neutrebbin, Germany, opposed the opening of new open pit mines, upholding that a continued reliance on fossil fuels was against the energy transition (Karohs, 2013). In Barendrecht, Netherlands, the local stakeholders asserted that the government was providing funding to pollute, which deviates from the "the polluter pays" principle (Oltra et al., 2012).

4.1.4. *Urban and rural environments*

Five projects were intended to be implemented in cities, two of which had negative experiences and three of which were accepted or potentially accepted. The failed project of Barendrecht was intended to be developed in a depleted gas field under the city of Rotterdam but raised concerns about public health and CO_2 monitoring (Oltra et al., 2012). In the city of Carson, California, the focus of attention was on environmental justice issues, the product of the construction of a polluting plant in an already contaminated area (Bradbury and Wade, 2010). The studied projects in Japan and Norway were planned in urban areas. Tomakomai and Yubari are heavily reliant on carbon-intensive industries; Yubari in particular was feeling the negative effects of the decline of coal mining and was therefore open to new industrial developments (Mabon et al., 2017; Mabon and Shih, 2018). In Porsgrunn, the community was very receptive to developing carbon capture in the city, as they saw it as an effort of their industries to solve environmental

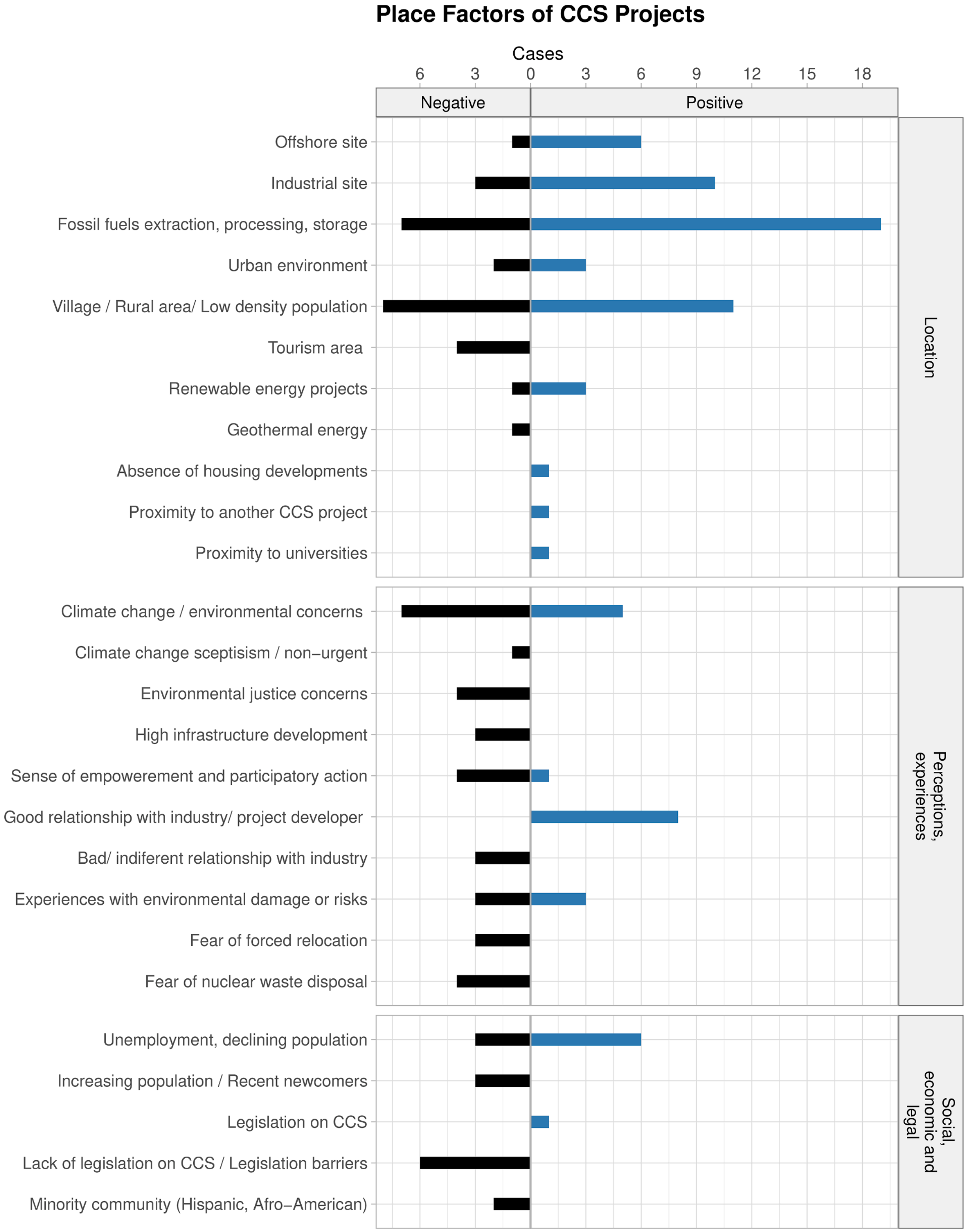

Fig. 3. Place factors mentioned as relevant for the success of projects. The place factors comprise the location characteristics relevant for the acceptance or opposition of projects. The bars indicate the number of projects that encountered a negative or positive reception of the communities for which the place factor was relevant.

problems (Haug and Stigson, 2016).

Choosing rural areas or towns does not necessarily improve the acceptance of projects. In the little town of Beeskow, Germany, the community was interested in conserving the landscape aesthetics and developing nature tourism, which contributed to the opposition to the facility (Dütschke, 2011). Groups in Greenville, Ohio, took offense to the idea that CCS projects should go ahead in less densely populated areas, understanding it to mean that rural lives are less valuable than urban lives (Hammond and Shackley, 2010).

4.1.5. Tourism

Communities who lived in a touristic area or planned to develop one did not agree with developing CO_2 storage in their vicinities. In the town of Beeskow, Germany, the community was interested in renovating the historical town center and developing nature tourism. They perceived that a CCS site would make the village less attractive for tourists (Dütschke, 2011). In Załęcze and Żuchlów, Poland, people's desire to develop tourism close to a natural reserve was an opposing argument when the anticipated effects of a CCS project were perceived to interfere with this goal (Brunsting et al., 2015). Despite this, the attraction of visitors was perceived as a positive side effect of the development of innovative facilities in non-touristic areas (see 4.4.2 Reputational gains).

4.1.6. Other location characteristics

Other location characteristics perceived to have affected the social fit of projects are proximity to universities, proximity to another CCS project, agriculture, presence of renewable energy projects, and plans for developing geothermal energy.

Proximity or the involvement of universities, such as in FutureGen, was linked to the involvement of a trusted third party (Hund and Greenberg, 2010). Proximity to another CCS enterprise helped the Boundary Dam project build on the already existing public awareness and understanding of CCS (Lockwood, 2017). In Germany, the presence of renewables was a sign of a "green" focus of the region, in contrast to CCS being linked to fossil fuels, which was seen as contributing to "business as usual" (Inderberg and Wettestad, 2015).

The pervasiveness of agricultural areas in Greenville, Ohio indicated that the region was unfamiliar with industrial developments (Bradbury, 2012) and represented an opportunity for the Weyburn and Otway projects, as farmers perceived compensation as a chance to secure their livelihood and minimize fluctuating incomes (Anderson et al., 2012; Boyd, 2015). In Bełchatów, Poland, a perceived risk of the CCS project was the potential conflict between the CO_2 storage site and a geothermal project, which brought socio-economic benefits for the region (Oltra et al., 2012; Lockwood, 2017).

4.2. Social, economic, and legal place factors

4.2.1. Employment and population trends

Unemployment, low socio-economic status, and/or a declining population were important factors for the acceptance of projects Hontomin in Spain, Don Valley in the UK, FutureGen 1.0 in the US, and Yubari in Japan (Hund and Greenberg, 2011; Reiner et al., 2011; Oltra et al., 2012; Mabon and Shih, 2018). Some of these communities have suffered depopulation due to a lack of economic opportunities. Therefore, those communities found economic benefits in the CCS projects derived from employment in power plants, money from fossil fuel extraction, or an increase in tourism around the innovative installations.

In contrast, the increasing population of Beeskow, Barendrecht, and Greenville might have contributed to the opposition to projects (Brunsting, de Best-Waldhober, Feenstra, and Mikunda, 2011; Dütschke, 2011; Bradbury, 2012). The residents of these areas were economically healthy, and their plans diverged from the future that the projects envisioned. Probably due to this reason, the absence of housing developments was thought to contribute to the acceptance of the Future Gen 1.0 project in Matton (Lockwood, 2017).

4.2.2. Legislation

The lack of legislation dealing with long-term liability was a point of tension in several German cases, as well as in Jamestown, New York and Greenville, Ohio. In Germany, by the time several CCS projects were proposed, the country did not have legislation on CCS. In the Jänschwalde project in Brandenburg, this originated a conflict around the company's short liability time span, which citizens interpreted as the company's intention to strive for profit maximization with a minimization of losses (Karohs, 2013). Similarly, in Greenville, there was no state legislation that addressed liability associated with the development of CCS projects. Therefore, the issue of who would be accountable if something went wrong was a major issue from the outset (Bradbury, 2012).

4.2.3. Minority communities

The presence of minority communities and associated environmental justice problems was a topic in two cases in the US. In Carson and Thornton, California, the African-American, Hispanic, and other disadvantaged communities perceived discrimination in the selection process, as they were already burdened with the existing industrial developments and associated environmental problems (Wong-Parodi et al., 2009; Bradbury and Wade, 2010).

4.3. Perceptions and experiences

4.3.1. Climate change concerns

Concerns around climate change encouraged support for CCS projects when climate change was perceived as an imminent risk. Conversely, a strongly held belief that climate change is not occurring or that there are better strategies to tackle it negatively affected attitudes toward CCS. The prolonged drought that Australia was experiencing when the Otway CO2CRC project was initiated raised awareness among farmers about the importance of CCS. Farmers were sympathetic to CCS technology, as it would help address the consequences of climate change (Anderson et al., 2012). In Greenville, some vocal opponents disputed the reality of climate change, questioning its scientific basis and, therefore, the need for carbon mitigation technologies (Bradbury, 2012). Other opponents expressed the belief that instead of a project that promoted the continued use of coal, renewables would suffice to mitigate potential problems (Bradbury, 2012).

4.3.2. Justice: Environmental justice and infrastructure development

Former negative experiences with environmental risks or infrastructure development caused projects to be seen as an addition to a sum of injustices. The community in Barendrecht in the Netherlands felt that it had already been subjected to the construction of a fair share of industrial infrastructure and did not want to continue developing in this direction (Kuijper, 2011). In Carson, US, the largely ethnic and relatively poor population complained about having to host excessive industry and infrastructure projects, as this would increase air pollutants in an area already suffering from air quality issues (Bradbury and Wade, 2010).

4.3.3. Sense of empowerment and participatory action

Communities who felt unempowered to change outcomes according to their history of community and industry relations felt they also lacked the power to influence future decisions and decide on risks (Wong-Parodi et al., 2009). In Thornton, US, the community was afraid of government and corporate neglect in case the technology did not perform as expected. Thornton had a long-lasting problem with water quality due to lead pollution from a cannery and felt that its voice was not heard by the local government (Wong-Parodi et al., 2009). In the Brandenburg state in Germany, residents claimed that they were not respected by the government when it came to having a say in the decision-making processes. With the CCS project, they felt used as objects of experimentation and not as a community that could decide about its trajectory (Schulz, Scheer, and Wassermann, 2010; Karohs, 2013).

4.3.4. Relationships

Having a positive established relationship with the industry made the implementation processes smoother. In the case of ROAD, Netherlands, the developers were already present in the area, and local stakeholders and municipalities found it difficult to be too critical with the important employers of the area (Reiner et al., 2011). In Future Gen, the project benefited from strong relationships with development agencies and the Geological Survey. In addition, the project gave citizens genuine opportunities to provide input into project decisions, which definitely contributed to building a positive relationship (Bradbury, 2012). On the other hand, the Greenville relationships with the ethanol plant where the CO_2 was going to be captured had been negatively affected by the depletion of their water wells following the plant's start-up just a few months before (Bradbury, 2012). Similarly, a study in Germany found that the acceptance rates of CCS were lower in coal-mining regions, a phenomenon likely explained by the previous negative relationships with the local fossil fuel and energy industries (Braun, 2017).

4.3.5. *Experiences with environmental damage or risks*

Experiences with environmental risks were problematic for project implementation when they were associated with a lack of institutional support. This was the case for Thornton and Greenville, who had had negative experiences with water pollution and depletion, respectively, in a context of weak institutional support (Wong-Parodi et al., 2009; Bradbury, 2012). Therefore, the public associated these experiences with a potential lack of institutional response to risks. On the other hand, negative experiences were non-problematic when the risks were properly managed by the authorities or were distant in time. For example, in Lacq, France, the project was developed in an area where there had been extraction of a very corrosive type of natural gas. Local institutions have shown for more than 60 years that they can successfully deal with dangerous gas and pipeline risks, which inspired trust in the population (Ha-Duong et al., 2011). In Ketzin, an underground reservoir of natural gas caused leakages in 1965, and a small village had to be relocated (Dütschke, 2011). Therefore, the CCS project involved injecting only minor quantities of CO_2, and the project managers promised that the operations would be stopped in case of leakage (Dütschke, 2011). In Japan, as earthquakes are a particular concern, a seismometer was installed to continuously monitor seismicity in the area and release real-time data (Lockwood, 2017).

4.3.6. *Other perceptions and experiences*

Fear of forced relocation for the opening of new coal mines in Beeskow and Neutrebbin, Brandenburg and nuclear waste disposal in all the projects in Germany contributed to the opposition of the population. In Brandenburg, forced relocation was perceived to be part of the domino effect of coal power generation connected to the proposed CCS project of Jänschwalde (Karohs, 2013). Moreover, the potential unexpected consequences of a long-time-frame technology were mentioned in Schleswig-Holstein, referring to an accident resulting in radioactively contaminated water close to the Asse nuclear waste repository (Karohs, 2013).

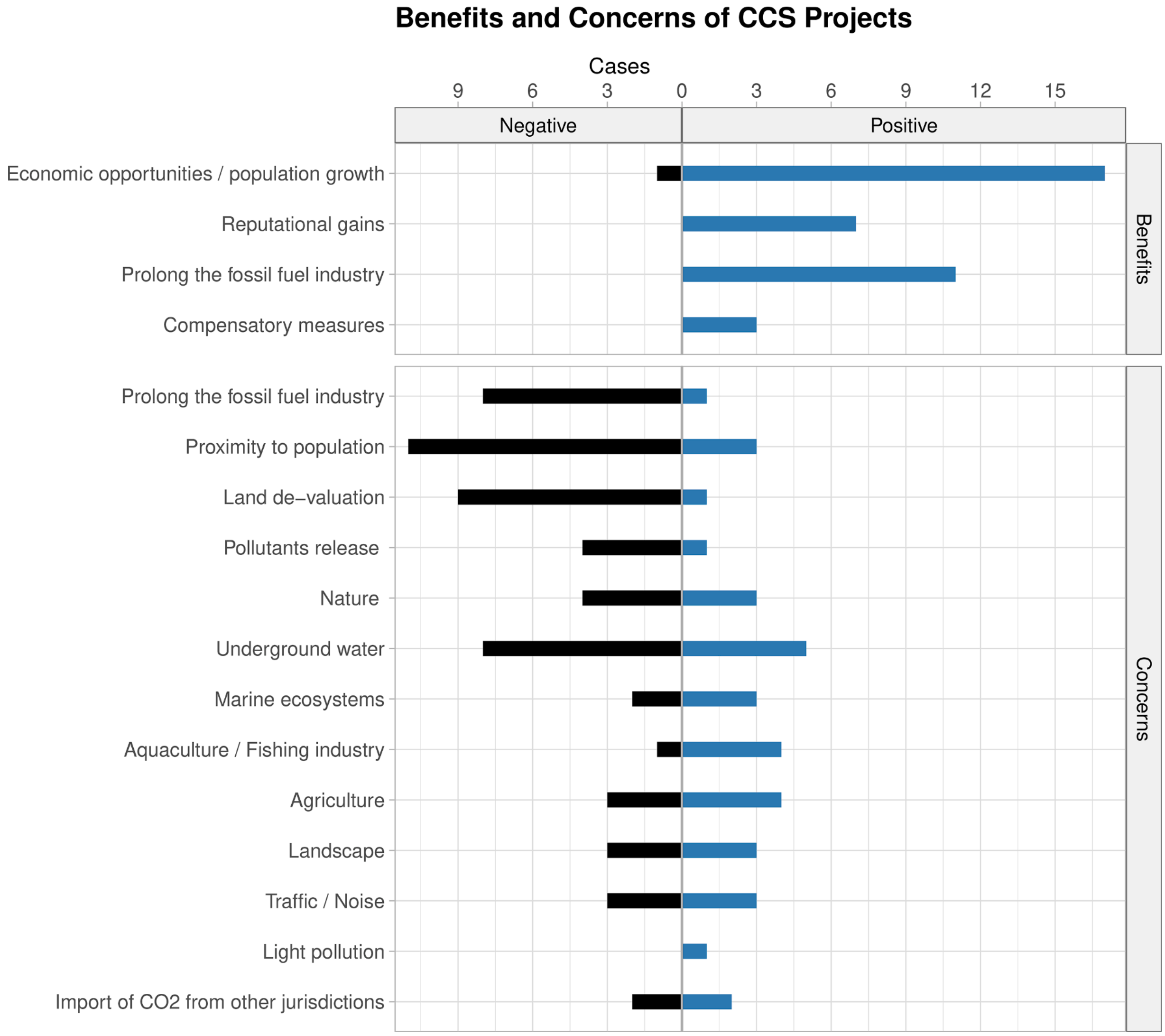

Fig. 4. Benefits and concerns raised by publics who accepted or opposed the projects.

4.4. Benefits and concerns

In addition to the characteristics of locations and their communities that were relevant for the emplacement of projects, different benefits and concerns were raised after the projects were proposed, therefore influencing their evolution (see Fig. 4).

4.4.1. Economic opportunities

Economic opportunities and job creation were mentioned as relevant factors for the acceptance of 15 out of 18 accepted projects. Power plants provide jobs, while enhanced oil recovery (EOR) resources from oil extraction and innovative facilities attract visitors. In the EOR project in Weyburn, related benefits of economic prosperity allowed younger residents to remain or return to the area, therefore increasing the value of properties (Boyd, 2015). The Weyburn area is characterized by a long history of oil extraction, and the industry is a major employer in the area (Boyd, 2015). Nonetheless, in other communities, the economic benefits were outweighed by urgent concerns, such as environmental justice issues in Carson or the lack of innovation benefits in FutureGen II (WRI, 2010; Bradbury, 2012). Furthermore, in marine areas where fishing is an economically significant activity, CO_2 storage was considered a threat (Mabon et al., 2014, 2017; Brunsting et al., 2015).

4.4.2. Reputational gains

Technological advances expected to lead to economic and reputational gains were generally well received in communities that were open to innovation and felt proud of being hosts. This was the case in Ketzin, Hontomin, Otway, FutureGen, and Tomakomai. In Ketzin, due to the innovativeness of the project, the national and international media reported about the project, and the community expressed interest in developing tourism for visitors at the CCS plant (Dütschke, 2011). Quoting the head of the stakeholder engagement team in Hontomin, “People really liked the fact that their little village was on the global map when it comes to this technology—that meant that people didn’t just accept the project, they really wanted to get behind it and make it work” (Pragnell, 2013).

4.4.3. Compensatory measures

Financial compensatory measures were positively received in the cases of Otway, Australia, and Weyburn, Canada, but viewed with suspicion in the Jänschwalde project, Germany. In Otway, the compensation payments for farmers for siting pipelines and gas wells were considered to contribute to fluctuating incomes at a time of drought and transition (Anderson et al., 2012). Similarly, in Weyburn, the presence of the oil industry and the income it provided through secondary job opportunities or the leasing of land for wells and pump jacks offered a way for farmers to retain the land and their livelihood (Boyd, 2015). On the other hand, proposals of compensation to the residents in the Jänschwalde project (with potential storage sites in Beeskow and Neutrebbin) were met with suspicion and regarded as evidence that the project was unsafe (Lockwood, 2017).

4.4.4. Prolongation of the fossil fuel industry

The extension of the fossil fuel industry represented a benefit or a concern in different contexts. Projects that proposed prolonging the fossil fuel industry through EOR or by building or extending the life of oil, coal, or gas power plants were welcome in areas familiar with the industry. Economic opportunities were mentioned, as power plants provided jobs and EOR money from oil extraction (see 4.1.3 Areas of fossil fuel extraction, processing, and/or storage).

Fossil fuel power stations were not welcome in areas that disagreed with extending the fossil fuel industry. For instance, in Jamestown, New York, groups were opposed to the construction of a “clean coal” plant, arguing that the prioritization of clean coal over other power supply alternatives was unfounded (WRI, 2010). In Carson, California, a new power plant using petcoke was to be sited in an area with preexisting air quality problems, which were already a major issue for groups advocating for environmental justice and opposing the continued use of coal (Bradbury and Wade, 2010). In Germany, the projects were perceived as competition for renewables and the energy transition (Inderberg and Wettestad, 2015).

4.4.5. Health and safety of ecosystems and humans

Concerns over health and safety were mentioned by the publics of most of the reviewed projects, both accepted and opposed. People showed concerns about the potential harm to people and damage to the properties close to the storage sites caused by induced seismic events, pollutant release from new industrial plants, fall of property values, and damages derived from CO_2 leakage, such as the possible asphyxiation of humans and animals or pollution of underground water and damage to vegetation, the fishing industry, and marine biodiversity.

These concerns were common among all projects but played a major role in certain cases. In Beeskow, people were highly concerned with a potential leakage that could cause fatal accidents and groundwater contamination (Oltra et al., 2012). At Barendrecht, the potential negative impacts on public health and the monitoring of CO_2 were the main public concerns, fueled by a lack of serious consideration of the public’s position (Feenstra et al., 2010; Brunsting et al., 2011; Correljé et al., 2015).

4.4.6. Aesthetics

The construction and operation of CO_2 capture or storage facilities raised concerns over the visual impact on landscape, light pollution, and noise effects. In Beeskow, the opponents were afraid of the negative impacts that these changes would have on the real estate market and tourism (Oltra et al., 2012). The perceived visual impacts of the installations were also a concern for the potential sites of Załęcze-Żuchlów, Poland, and Moray, Scotland (Brunsting et al., 2015). The increase in traffic and noise derived from the construction of facilities or pipelines was also mentioned in the cases of ROAD, Weyburn, and FutureGen 1.0 (Hund and Greenberg, 2011; Reiner et al., 2011; Boyd, 2015).

4.4.7. Import of CO_2 from other jurisdictions

The prospect of a CO_2 pipeline raised concerns in communities around the RWE project, Germany, where the CO_2 capture was planned in the state of North Rhine-Westphalia and the storage was planned in the state of Schleswig-Holstein. The idea of locating capture and storage in different areas became controversial. The inhabitants of Schleswig-Holstein were concerned about the risks of pipeline leakage and groundwater acidification and did not perceive any benefits in the project (Inderberg and Wettestad, 2015; Lockwood, 2017). The situation was worsened by the opinion that RWE did little to engage stakeholders and by Greenpeace’s radioactive waste-like narratives (Inderberg and Wettestad, 2015). Conversely, the area of Weyburn, Canada, agreed to receive CO_2 from the Boundary Dam project. The EOR proposal also found high community support, as residents trusted the developer and the oil fields contributed to the local development and economic stability of the area (Boyd, 2015).

4.5. Summary

The literature on public responses to CCS projects indicates that the social fit of carbon capture and/or storage facilities has been influenced by the characteristics of places and projects. A variety of place factors, namely location characteristics, mediated the reactions of publics with respect to the projects’ implementation processes. Place factors had different effects on different project sites, depending on how they were interpreted by local actors. The key place factors that contributed to the acceptance or rejection of projects in the reviewed documents were local development plans, publics’ perceptions of inclusion and justice, experiences with similar actors and topics, socio-economic characteristics of the community, and legal status of CCS in the region.

The projects provided benefits but also raised concerns in the prospective communities. All the accepted projects offered value to the local population in terms of economic opportunities, identity, and reputation. Both the accepted and rejected projects raised some concerns in the communities—for instance, the question of fairness and the potential impact on health, local resources, and practices. Depending on the type of project proposed and the narratives involved, particular bundles of place factors and associated benefits and concerns were activated. In the following section, we explore whether maps can help visualize place factors, identify particular bundles, and trigger reflections on their potential effects when screening a large number of potential storage sites.

5. Results: GIS mapping of selected place factors

After identifying in the literature place factors that have influenced the acceptance of CCS projects, we proceeded to do the mapping exercise. For this, we selected points that represented potential CO_2 storage sites in Switzerland and mapped the geographical proxies of the identified place factors.

5.1. Selection of place factors

The authors selected place factors that they considered context-relevant and for which readily available data existed (see Table 1).

Table 1
List of place factors that the authors considered context-relevant for Switzerland and the corresponding available geographical data

Place factor	Context-relevant	Readily available
Location		
Offshore		
Industrial site	●	●
Urban or rural area	●	●
Tourism area	●	●
Renewable energy projects	●	
Geothermal energy	●	●
Absence of housing developments	●	
Proximity to another CCS project		
Proximity to universities		
Social, economic and legal		
Unemployment	●	●
Population trends	●	
Legislation on CCS	●	
Minority community		
Perceptions and experiences		
Climate and environmental concerns	●	
Climate change skepticism		
Environmental justice concerns	●	
High infrastructure development	●	
Sense of empowerment	●	
Relationship with industry	●	
Experiences with environmental risks	●	
Fear of forced relocation		
Fear of nuclear waste disposal	●	●
Benefits		
Economic opportunities	●	
Reputational gains	●	
Prolongation of the fossil fuel industry		
Compensatory measures	●	
Concerns		
Proximity to population	●	
Property value	●	●
Pollutant release	●	
Nature	●	●
Underground water	●	●
Marine ecosystems		
Aquaculture/fishing industry	●	
Agriculture	●	●
Landscape	●	●
Traffic/noise/light pollution	●	
Border between jurisdictions	●	●
Prolongation of the fossil fuel industry	●	

Context relevance was assessed based on parallels with siting controversies for other large renewable energy infrastructures in Switzerland, such as geothermal energy or hydropower (Ejderyan et al., 2020; Tabi and Wüstenhagen, 2017). Readily available geographical data served as a complete or partial representation of many of the factors. Factors such as previous relationships or justice perceptions could not be visualized.

We searched for geographical data that could be representative or serve as a proxy for the place factors mentioned in the section above. Readily available statistical and geographical data were obtained from federal offices. For the widespread factors, we took the indicators that highlighted major aspects of concern (see Table 2).

5.2. Mapping of place factors

We found 65 points where there had been oil and/or gas exploration in Switzerland. Today, there is no exploration or exploitation being done in the country. We visualized all the indicators in the buffers created around potential CCS sites on the map of Switzerland. In the case of variables that required data classification (employment and private housing), the intervals were defined using natural breaks for a given number of clusters of data. These breaks grouped similar values and maximized the differences between clusters. The obtained map shows the place factors outlined around the potential CCS sites (see Fig. 5).

Industrial zones, heritage sites of national importance (ISOS), protected underground areas, cantonal boundaries, and small patches of protected landscape are widespread among the selected locations in the country. In contrast, tourism, future geothermal projects, and natural areas are present only in a few locations. Employment is high throughout the country, particularly in the northeastern part, followed by the southwestern and southern regions.

Bundles of place factors present in single locations can be observed in Fig. 6. An exploration of the combination of place factors in individual locations can establish the basis for anticipating the social fit of a project by identifying trade-offs and potential directions for further research.

Comparing adjacent locations is key for deciding which site might potentially have a better social fit (see Fig. 7). Detecting the presence of particular single factors or a combination of them might constitute a strategy for including or excluding locations. Additionally, social research should expand on the details and additional elements of the physical or social characteristics of the locations.

For instance, in the first example displayed in Fig. 7, both sites A and

Table 2
Data used for the mapping of place factors in Switzerland

Place factor	**Indicator**	**Unit**
Industrial zone	Industrial areas; land use statistics NOAS04 2013–2018 (FSO, 2020)	ha
Employment	Employment rate per district 15–64 years old (FSO, 2018b)	% (mean)
Tourism	Hotel industry: supply and demand of open establishments in 100 municipalities in 2018 (FSO, 2019)	Number
Natural parks	The Swiss National Park and parks of national importance (FOEN, 2019c)	m^2
Geothermal energy	Present and future projects of geothermal energy (Swisstopo, 2019a)	Number
Landscape	Federal Inventory of Landscapes and Natural Monuments (FOEN, 2019a)	m^2
Groundwater	Groundwater protection zones (FOEN, 2019b)	m^2
Private housing	Private housing (FSO, 2017)	Number (median)
Cultural Areas	Heritage sites of national importance (FOC, 2019)	Number
CO_2 from a different political unit	Cantonal boundaries (Swisstopo, 2019b)	Number
Oil and gas extraction or storage	Energy raw materials: deposits (Swisstopo & SGTK, 2019)	-

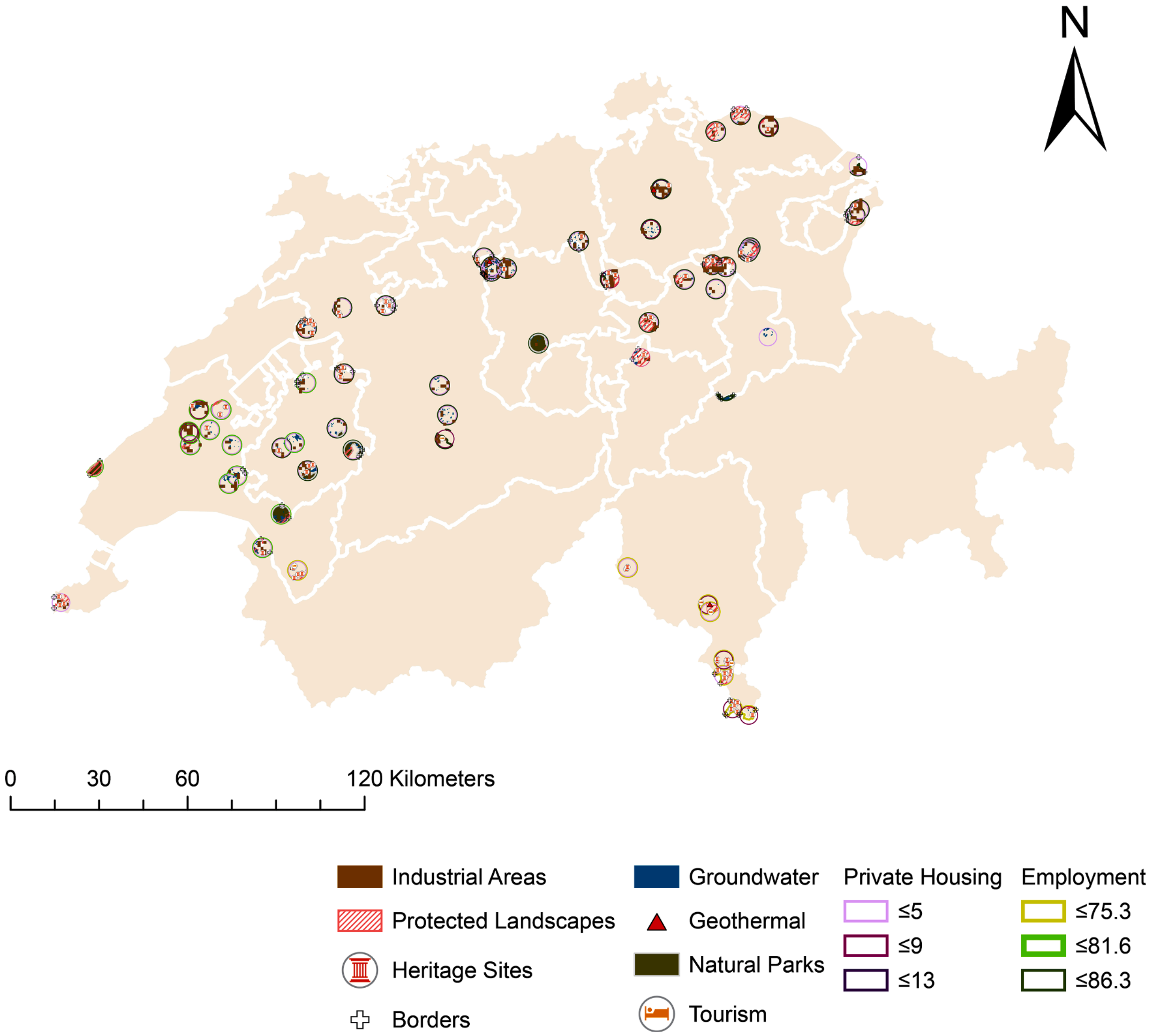

Fig. 5. Mapping of indicators on Switzerland at a small geographical scale. The indicators are mapped in a buffer around former gas and oil exploration and exploitation sites as proxies of potential CCS locations. The zoom-in box shows the profiles of some of the potential locations in more detail.

B seem to be inappropriate for a CO_2 storage project. However, site A might represent a better social fit due to the lack of a border, yet both sites have high employment, heritage sites, and a large area of protected landscapes, which might be linked to needs and identities that are not in line with a CO_2 storage project. When considering site B, the ethical implications of imposing risks on communities located across the border should be discussed, as they might be unable to express concerns through legal or political procedures and might not benefit from the project, for instance in terms of tax revenue.

In the second example, site C might have a better social fit than site D. The industrial character of site C might be more appropriate than the natural park with large groundwater protected zones in which site D is situated. The ethical implications of choosing an area that might be burdened by industrial development should be discussed. Additionally, the identity that the community derives from the industrial site should be explored further, as well as the implications of being located on a cantonal border and having a heritage site and some protected landscapes. An additional assessment could explore community values and needs and corresponding risk mitigation measures—namely, changes in the project's value proposition, design modifications according to local concerns, and an implementation process tailored to the local characteristics.

6. Discussion

We found evidence of 38 CCS projects for which the social fit was mentioned as relevant for the public's response. Additionally, we showed that maps can partially constitute visual representations of place factors around potential CCS sites and help to gain an overview of locations from a social standpoint. In this section, we use our findings to discuss how an understanding of place factors and their visualization can inform future site selection processes by providing a tool to reflect on the social fit of a project and its potential locations.

6.1. Influence of place factors on communities' responses to CCS

Our results show that place factors, namely a specific group of locational characteristics and associated benefits or concerns, are activated by the proposal of a project. Place factors emerge differently according to the characteristics of the location and the significance they have for communities. This supports previous research stating that people do not think about technologies or risk in isolation (Rogers, 1998). Conflict is not only directed to the risks of the technology but is also related to a broader set of sociocultural issues (Wade and Greenberg, 2011, citing Bradbury, 2005), leading to vastly different siting

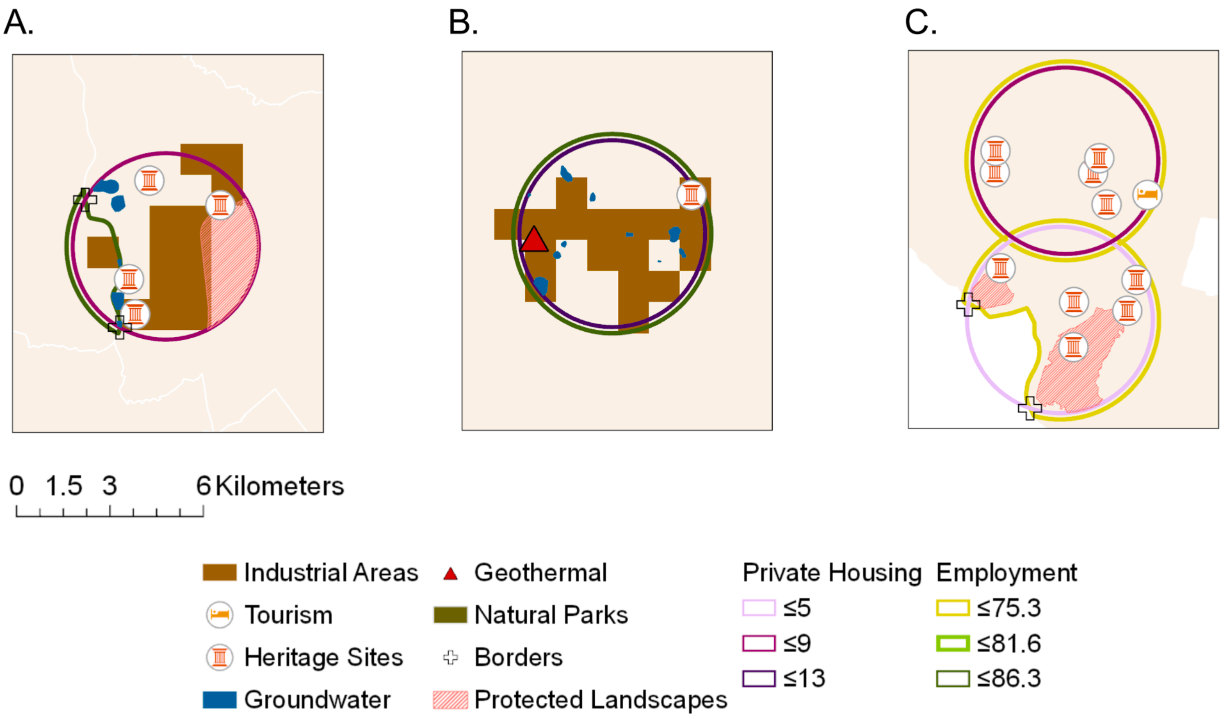

Fig. 6. Mapping of indicators at a large geographical scale with bundles of place factors. In place A, there is a strong presence of industry, heritage sites, and protected landscapes. Trade-offs in decisions would likely have to be made. Place B is an area with a high density of private housing and high employment rates and locates a future geothermal project. The economic contributions of a CCS project might not represent a particular benefit for the region. Place C is relevant for tourism, as it has a high density of heritage sites and protected landscape. The expectations of the community might differ from those represented by a CCS project.

outcomes in different locations (Peterson et al., 2015).

Identifying the place factors that have played a role in the development of CCS provides a basis for researchers and project developers to understand how place shapes public reactions in relation to CCS projects. As a result, the notions of Not In My Backyard (NIMBY) or Yes In My Backyard (YIMBY), criticized for masking complex factors that contribute to communities' response (Devine-Wright, 2014), are, to some extent, disentangled by exposing the local impact, type of project, and history that contributed to the publics' reactions.

In the cases examined, particular bundles of place factors have repeatedly had an effect on the implementation of CCS projects. For instance, research facilities framed as globally innovative projects were well received in industrial areas that had experience with oil or gas exploitation, were located in towns or rural areas, and where the communities appreciated the reputation and economic benefits from the projects (WRI, 2010; Lupion, Pérez, Torrecilla, and Merino, 2013). In addition, in the case of fossil fuel projects that faced opposition, a frequent bundle of place factors comprised the disagreement with the continued reliance on fossil fuel, high concerns over human health, and a divergence between the development plans of the region and the one proposed by the project—for example, the presence of newcomers looking for calmness or plans of developing tourism (Feenstra et al., 2010; Hammond and Shackley, 2010; Bradbury, 2012).

These cases show that the provision of benefits valued by the population and the location in areas that "fit" with respect to landscape and offshore storage frequently contributed to the acceptance of the population. Local benefits in terms of economic improvements (through jobs, tourism, or investment in the community) and/or reputation were key for the success of projects, making benefit perception an important predictor of acceptance (L'Orange Seigo, Dohle, and Siegrist, 2014; Braun, 2017). The projects proposed in industrial areas were often more successful than the ones proposed in "natural" sceneries, as they did not disrupt the landscape and people were familiar with the risks (Wolsink, 2007; Batel et al., 2015; (Devine-Wright and Wiersma, 2020). Offshore projects often found less resistance than onshore ones, as these sites avoided concerns such as the effects on property pricing and risks to human health (Mabon et al., 2014; Schumann et al., 2014). The compensation measures contributed to a positive public perception of the project when the public expressed mild concerns about the consequences of potential CO_2 storage (Ter Mors et al., 2012).

Opposition appeared when the expectations of the community development (e.g., tourism) diverged from the future drawn by the CCS project (Dütschke, 2011; Braun, 2017). Moreover, a lack of legislation regarding liability has been problematic in many cases, as it probably heightens the public perception of riskiness and uncertainty, enabling the issue to become rapidly politicized (Lockwood, 2017). Negative experiences with pollutants and related responses of the government and corporations resulted in a loss of empowerment and fear of being neglected (Wong-Parodi et al., 2009). Concerns over human health, nature, and property values also contributed to the risk perception of the project (Hammond and Shackley, 2010; Oltra et al., 2012). Finally, location of the storage component offshore led to social concern when there was strong attachment toward the ocean (de Figuereido, 2003) or concern over marine ecosystems (Markusson et al., 2011).

Opposition also appeared when the population considered the siting of the CCS project in their locality unfair due to the fact that they would only serve as a storage site and not receive any benefit (WRI, 2010; Karohs, 2013); these communities believed that they had already contributed "enough" to the national infrastructure (Feenstra et al., 2010) or felt discrimination toward minorities during the siting process (Wong-Parodi et al., 2009; Bradbury, 2012). Compensation measures were considered inappropriate when they were completely unrelated to public concerns (Ter Mors et al., 2012). Finally, other controversies in time and place, such as associating the controversies around nuclear power with a CCS project (Karohs, 2013), became part of the discursive space of the implementation process (Cuppen et al., 2020).

Apart from leading to the acceptance of or opposition to particular projects, place factors had additional consequences on the engagement

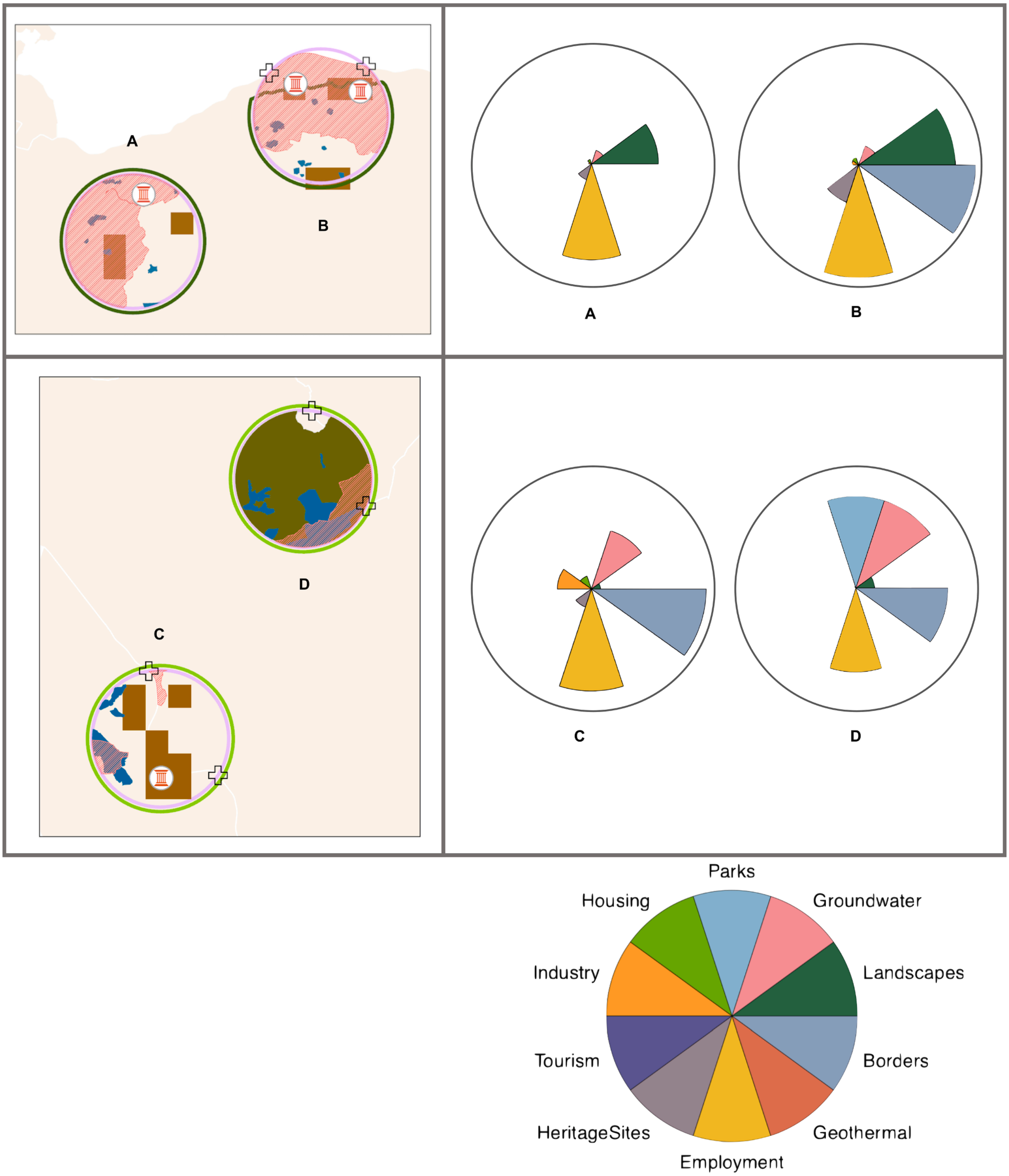

Fig. 7. Comparison of adjacent locations. The star plots adjacent to the maps reflect the combination of place factors within a location and differences between locations. Locations A and B are areas with similar place factors, yet B is located on the border of the country and has more heritage sites. C and D are located on cantonal borders and have large areas of vulnerable groundwater and small patches of protected landscape. D is part of a natural park, while C contains some industrial areas.

process where, for instance, agricultural areas were selected for the installation of pipelines and large numbers of farmers had to be involved in the engagement process or where seismic surveys had been conducted (Anderson et al., 2012; Lockwood, 2017). The cases that required the involvement of many people, either because they were located in an urban area or involved several municipalities or landowners, were challenging in terms of public engagement (Brunsting et al., 2011; Bradbury, 2012). Such configurations might increase the likelihood of opposition snowballing and require engagement with more people with diverse perspectives, resulting in less manageable situations (Hammond and Shackley, 2010). Finally, place factors have been relevant for risk mitigation measures, such as the implementation of an extensive monitoring system responding to the fear of earthquakes of the population in Tomakomai, Japan (Sawada et al., 2018).

6.2. *Visualizing and assessing place factors from maps*

Maps display some of the place factors of potential locations, providing an initial idea of the benefits and challenges that might be brought by a project under different scenarios. Maps can allow project developers to do a social screening early on in the process. The place factors that are actually activated by a project will depend on their significance to the communities according to the location's history, the project framing, engagement process, and implementation context. Additionally, the concept of place factors emphasizes the emotional relationships between people and location characteristics, meaning that place factors do not produce effects independently of the way they are interpreted by people.

A list of place factors relevant to the screened area can support discussions about the effects of said factors. The list can complement the maps by highlighting the possible negative and positive influences a specific place factor might have. The meaning and potential effect of each place factor will depend on the local history, project framing, and dominant narratives. While some place factors have a unidirectional meaning in communities (e.g., opposition to a clean coal project will likely appear in communities already bearing environmental burden), several factors in the list are present in both positive and negative cases, and their effect on acceptability varies depending on the local context (e.g., industrial areas can indicate that the population is used to such types of development and risks or that it feels burdened by high industrial development). Additionally, such a list is a necessary complement to keep track of non-mappable factors, such as experiences with environmental damage, relationships with the industry, or symbolic values assigned to non-remarkable features of the natural or built environment.

Based on the information reflected in the maps and lists, project managers can analyze the social fit of the project in different locations and narrow the number of potential sites. For example, exclusion criteria provide a way to reduce the number of potential areas for CCS and can be applied at the beginning of the screening process as a way to protect certain values—namely, to exclude locations that contain place factors that resist trade-offs with other values (Baron and Spranca, 1997). Factors of a single location might imply potentially contradictory effects, leading stakeholders to deal with trade-offs in their decision making. By highlighting such contradictions and potential trade-offs, maps are likely to lead project developers to consider place factors more carefully, as they will have to make choices based on them. The decision process can be supported by gathering new information on both mapped and non-mappable factors and adding new features to the map. Later on, the social characterization of potential locations can further identify context-relevant factors and confirm the potential benefits or concerns that the project might represent for communities.

Any potential values of community members and ethical consequences of developing the project should be considered in the narrowing process. Choosing a site because there are already industry-related nuisances and poorer communities less likely to oppose raises ethical questions, as in the example shown in Fig. 7. Not addressing such questions might show a lack of concern for local communities and, in turn, trigger opposition (Wong-Parodi et al., 2009). Being able to justify the choice or exclusion of sites on ethical grounds can support public engagement. Once a site has been chosen, the way developers engage the population in the process will also play a role (Vargas-Payera et al., 2020). More generally, while the anticipated acceptance of a potential site is a relevant aspect of the screening process, it should not be the only selection criterion, as there is no guarantee that local actors will interpret the place factors as project developers do.

While place factors' maps help construct an overview of potential locations, they limit access to information at particular scales and establish boundaries around locations. Important community values can be located outside delimited study areas, leading to a mismatch between the established boundaries and the benefits perceived by people. Moreover, larger cultural contexts, such as countries in which the projects are embedded, will influence the benefit and risk perception of communities, as they determine aspects such as uncertainty avoidance (Karimi, Toikka, and Hukkinen, 2016; Karimi and Toikka, 2018). Once some narrowing has been done, involving the public is irreplaceable for acquiring local knowledge of places, as the tools presented here can easily overlook local contingencies (for example, see Trutnevyte and Ejderyan, 2018).

7. Reflecting on the project design based on place factors

Adapting the identity of a project to the identified place factors can support the responsiveness to local concerns. At the beginning of the screening process, the choice of location might vary according to the compatibility of the project. Later on, the nature and framing of the project can be reflected and modified depending on the characteristics of a few potential locations (see Fig. 8). At this stage, the framing and engagement process of the project can be adjusted, and the potential benefits that the project will offer to the community can be defined. The communication around emerging concerns, mitigation measures, and benefits should all be reconciled.

Reflections about the siting of carbon storage facilities should start from the premise that technologies are not value-neutral but incorporate certain values while failing to represent others (Correljé et al., 2015). In the cases examined in this paper, values such as security of energy supply, sustainability, or innovation were highlighted differently. The acknowledgement of values in technological design creates the opportunity to proactively include public values in the stage of design in upstream phases (Correljé et al., 2015, citing van den Hoven, 2005). This is consistent with the goals of RRI, which calls for policies that anticipate the impacts of emerging technologies and reflect on the societal and ethical dimensions of research and innovation processes (Owen et al., 2012; Ribeiro et al., 2018).

The discussion of communities' preferences linked to place factors in particular locations provides a more nuanced understanding of the predominant values and enables adjusting the technology design. Including the public's voices in the decision-making processes can help to build trust and smooth the way for implementation (Beierle, 2005). Public participation also contributes to the formation of sustainable communities (Coenen, 2009) and can generate more substantive decisions when diverse knowledge and values are considered (Fiorino, 1990). Although anticipating place factors early on involves higher uncertainties about a community's preferences, avoiding the inclusion of place factors in upstream siting decisions is not a satisfactory choice. In the real world, landscape allocation decisions are made, and seemingly incommensurable human values are made commensurable, or at least prioritized, through choice and action (Brown, 2004). Although focusing on such complexities creates new challenges, it is essential to

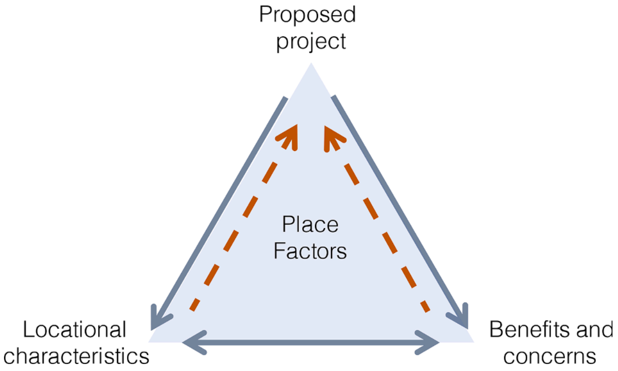

Fig. 8. A project entails the emergence of benefits (e.g., jobs) or concerns (e.g., induced seismicity). By choosing a location, the project activates locational characteristics (e.g., high unemployment), which will determine whether the benefits and concerns materialize (e.g., job creation) (blue arrows). Both the locational characteristics and corresponding benefits or concerns will generate feedback on the proposed project, allowing or impeding its implementation (red arrows).

do so when faced with a technology that significantly shapes our collective future (Bergmans et al., 2015).

7.1. Limitations

In this paper, we discussed how listing and visualizing place factors in maps can support an initial screening of potential sites by bringing in social criteria early on in the siting process. Implementing such a procedure must take into account several limitations to our study.

A first limitation concerns the identification of place factors. In this paper, we established a list of relevant place factors for the siting of CCS by reviewing academic and practical literature on the topics. All the cases analyzed in the reviewed documents are located in the Global North. Hence, the list of place factors identified here might not be relevant in a developing context and might overlook key place factors. Looking at the literature on the siting of other subterranean activities, such as mining or geothermal energy production, might provide information about contexts not covered by our corpus.

Another limitation is that not all relevant place factors can be easily represented on locational maps. This depends on the available data and mapping effort devoted to the exercise. As we already mentioned, elements such as existing social relationships between actors or values assigned to non-remarkable landscape features are difficult to represent. Such landscape values might result from social practices that are not taken into account by conventional approaches to mapping (Hirt, 2012). Some elements cannot be mapped without the involvement of local communities and are thus unlikely to be featured in maps for an initial screening. Although we suggest confronting the place factors mapped at specific locations with a complete list of potential place factors, there is a risk that the factors visualized will take pre-eminence in decisions if the screening is not reflected upon.

Focusing on place factors only in a defined area around a potential capture or storage site also implies several limitations. Using a standard radius to define the mapped area for place factors might lead to missing key factors located outside of the radius or overlooking communities outside the area. The latter case might especially occur in less densely populated regions (Vargas-Payera et al., 2020). Furthermore, such an approach is mainly adapted for projects with on-site capture and/or storage. As mentioned above, pipelines and intermediary storage facilities can also encounter acceptance issues (Inderberg and Wettestad, 2015; Lockwood, 2017).

As we showed previously, the bundle of factors activated by projects varies depending on their framing. Further work should examine in more detail the relationship between the technological framings of CCS and similar technologies and activated place factors. Project developers' records and interviews with concerned communities might provide valuable insights in this regard. Additionally, as some authors suggest, there is a significant gap between the participatory mapping processes and aspirational goals, which include extracting lessons from these mappings, increasing trust, and reducing conflict (Dietz and Stern, 2008; Brown, 2017). Therefore, an important point for further research would be how the framework presented here operates in a real setting: can power relationships upstream in the process be influenced? What are the benefits and challenges of introducing this approach when technical site-screening processes are being conducted?

8. Conclusions

This paper presented a tool for integrating people's concerns and location characteristics early in the site selection process of CCS projects when scanning large geographical areas. This tool makes it possible to bridge the gap between "sites" (locations that have abstract and distant meanings to project managers) and "places" (locations to which communities are familiar and emotionally attached). We identified relevant place factors that had a positive or negative effect on the acceptance of CCS projects. We detected that this effect varied depending on the project's framing, combinations between factors, and the interpretation of place factors by local stakeholders. Based on this, we introduced a procedure illustrating how lists and maps of place factors can improve the quality of decisions during the early phases of site selection processes by enabling project developers to take into account the emotional connections of residents toward their locale. This provides a platform to introduce ethical considerations in the selection and anticipate social values and risks when the involvement of local stakeholders is not possible or desired.

Further research is needed to establish a validation protocol for the tool we have presented here. While a pre-selection of sites can be made based on a GIS mapping of place factors, we suggest that any discussion of a limited number of options requires a deliberative process with the populations concerned. Indeed, while the lists and maps introduced in this paper allow for the consideration of place factors, their meaning in a given community cannot be interpreted without a thorough knowledge of local conditions.

Finally, our results challenge the notion that CCS is a controversial technology per se. They highlight that the choice of sites and how the technology is framed have played a key role in cases of public opposition to projects. Therefore, an evaluation of the suitability of potential locations that builds on how local values can be supported by the technology opens up potential trajectories for future projects. While this process requires some guidance on which place factors to concentrate on, it also demands flexibility to dive deeper into the local realities and consider the larger context of participatory and trust-building processes.

CRediT authorship contribution statement

Juanita von Rothkirch: Methodology, Investigation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Olivier Ejderyan:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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