



Original research article

# Lay perceptions of Carbon Dioxide Utilisation technologies in the United Kingdom and Germany: An exploratory qualitative interview study



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## ABSTRACT

Carbon Dioxide Utilisation (CDU) technologies convert Carbon Dioxide (CO<sub>2</sub>) into carbon-based products. CDU technologies are viewed as a means of helping to address climate change while creating commodities that can be sold to generate financial revenue. While technical research and development into CDU options is accelerating, at present there has been little research into public acceptance of the technology. The current study presents the findings of a series of 28 exploratory interviews conducted with lay people in the United Kingdom and Germany. The results show that awareness of CDU is currently very low in both countries but that there is tentative support for the concept. This support is, however, caveated by considerations of the techno-economic feasibility of the technology and the societal consequences that might result from investment. While the thematic content of discussions was similar in both countries, where appropriate any notable differences are outlined and discussed. In addition to providing fresh insight into the emerging nature of public perceptions and acceptance of CDU, it is reasoned that the findings of this research could help to benefit the design of communication materials intended to engage lay-publics in debate about the nature and purpose of CDU technologies.

## 1. Introduction

Carbon Dioxide Utilisation (CDU) technologies—also often referred to as Carbon Capture and Utilisation (CCU) or Carbon Capture and Reuse (CCR) technologies—convert Carbon Dioxide (CO<sub>2</sub>) via physical or chemical processes into saleable carbon-based products (e.g. polymers, methanol). By making use of waste CO<sub>2</sub> released by large point-source emitters (e.g. fossil-fuel power generation, steel manufacture, etc.) or directly from the air; CDU technologies are viewed as a means of helping to address climate change—consistent with emerging national and international policy and legislation (e.g. that precipitating from the ‘Paris Agreement’ at COP21, see [1])—while broadening the raw material base and creating commodity products (e.g. chemicals, plastics, cement, fuels, urea) that can be sold to generate economic revenue [2].

The concept of CDU is not new and there are already mature markets for CO<sub>2</sub>-based products like urea and sodium carbonate; however, there is growing interest in a variety of new CDU options, including CO<sub>2</sub>-derived fuels (e.g. methanol, formic acid) and other chemicals (e.g. acyclic carbonate, polyurethanes), which still remain at various stages of research, demonstration and feasibility testing [3,4]. Crucially, while

technical advancement of these options is accelerating, there is currently little research into the public (and broader social) acceptability of the technologies and related product options (see [5]).

The present study used exploratory semi-structured interviews in order to learn more about the nature of emerging lay-public opinions of the technology in the United Kingdom (UK) and Germany. There was a particular focus on the anticipated conceptual, techno-economic and societal risks and benefits of the technology (see [6]). The UK and Germany present a particularly interesting context for such investigation in Europe, due to their prominent and advanced technical CDU research and development programmes [7–9].

The remainder of this introduction first outlines the importance of studying the public acceptance of technological innovation (Section 1.1), before summarizing what is currently known about public perceptions of CDU (Section 1.2). It ends by outlining the specific aims and objectives for the current study (Section 1.3).

### 1.1. Public acceptance of technological innovation

The key role that lay-publics (e.g. in their roles as voting citizens and product consumers) have in shaping the success of technological

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innovation at national, local and household levels (e.g. prospects for investment, the ability to find sites, etc.) [10–12], has led to calls for earlier and more participatory engagement of such publics in discussions regarding technological and policy innovation [13–16].

This is of particular importance within Westernised democracies, where policy and institutional change typically requires the support of individuals and communities [17]. Indeed, there are a number of instances where failures within public engagement and deliberation have led—at least in part—to delays or curtailments to the introduction of new technologies at both national (e.g. *GM agriculture*, e.g. [18]) and local levels (e.g. *renewable energy technologies*, e.g. [10]).

If correctly resourced and planned, such engagement activity can yield benefits for proponents of a given innovation [19,20]. Timely and meaningful engagement *can* for instance: (a) generate public trust in decision-makers and promote acceptance (or tolerance) of decisions; and (b) yield key insight into the emerging subjective perceptions of the technology (e.g. the perceived risks and benefits), which can make a substantive contribution to decisions being made about the technology (see [21]). For example, expert and lay judgments about the type and severity of risk posed by hazards (including new technologies) can deviate markedly from one another [22]. By engaging with affected publics it can be possible to identify areas of divergence, which can be useful in designing tailored education and communication strategies [23].

As an example, social scientific research into the lay-public perceptions of Carbon Capture and Storage (CCS) is now fairly mature. CCS technologies capture CO<sub>2</sub> emissions from large point-source emitters (e.g. power plants), allowing for the transportation of the CO<sub>2</sub> to deep-geological storage sites (e.g. depleted oil and gas fields) [24,25]. The social scientific studies that have been conducted to date have yielded key insight into attitudes towards the technology among diverse publics (e.g. affected populations, nationally representative samples) and other stakeholders in a number of countries [26–28]. In addition to identifying some of the perceived risks and benefits of CCS (see [29]), this research has provided a basis for the creation of public-engagement programmes and communication materials designed to prompt more informed discussion about the processes and principles of the technology [30–32].

In short, while the ‘public face’ of technological innovation is often an afterthought (see [33]); elucidating and integrating the opinion of lay-publics (alongside those of other social-stakeholders) into technological design, development and deployment should be considered a priority.

### 1.2. Public perception of Carbon Dioxide Utilisation (CDU)

Due to the conceptual and semantic overlaps between CCS and CDU—and the fact that CDU can be affiliated with CCS operations [2,34]—it could be tempting to draw inferences about the probable lay-public response to CDU from the extant literature on CCS. There are, however, limitations to this, not least due to the inherent differences in the nature and intended purpose of these technologies.

The *raison d'être* of CCS is to combat climate change and thus public perceptions of CCS are strongly determined by beliefs in anthropogenic climate change and the perceived utility of CCS in combating this threat [29,35]. While CDU *can* also result in net reductions in CO<sub>2</sub> emissions, the prospect of also creating products and generating economic revenue provides a secondary purpose for investment in the technology. Furthermore, as CDU does not necessitate the geological storage of CO<sub>2</sub>—a commonly registered grievance with CCS—it is reasonable to hypothesise that attitudes towards CDU might differ from those held about CCS [36].

While still at an early stage, initial attempts at conducting systematic assessments of lay-public perceptions of CDU technologies and product options are beginning to emerge (e.g. [6,37–39]). For example, Jones et al. [6] conducted a focus group study with adults and high

school children in the UK. In addition to confirming the low level of existing public awareness about CDU, the research highlighted some of the emerging themes in lay-public discourse about the technology. These themes centred on: (1) issues relating to the general concept (“*should we do this?*”); (2) technical issues (“*can we do this?*”) and (3) societal consequences (“*what will happen if we do this?*”). More specifically, *concept* discussions focused principally on the value of CDU in addressing climate change. While some participants valued CDU as a means of ‘buying time’ in the fight against climate change, others questioned the efficacy of CDU as a long-term solution to the problem (e.g. due to the eventual re-release of the captured CO<sub>2</sub>). *Technical* discussions tended to centre on concerns about the high capital-costs required to bring CDU technologies and products to market, as well as questions about the cost-effectiveness and thermodynamic efficiency of CO<sub>2</sub> conversion processes. In terms of *social consequences*, participants spoke about a range of issues, including perceived inconsistencies between investment in CDU and societal drives towards sustainability. For example, some viewed CDU as something that might encourage societal complacency in reducing carbon emissions, while others believed that CDU could be seen as a motivating exemplar of efforts being made to address this issue.

van Heek et al. [38] also recently published research into the antecedents of consumer perceptions for a CDU-derived mattress. In addition to confirming that participants tended to have relatively positive perceptions of CDU (particularly relative to storage of CO<sub>2</sub>), the findings also confirmed a number of things about the factors that might govern the acceptance of consumer products derived from captured CO<sub>2</sub>. For example, the proportion of CO<sub>2</sub> used within the product (*CO<sub>2</sub> proportion*) was not a particularly strong predictor of product acceptance. By contrast, both: (a) the carbon emissions affiliated with a CDU-derived mattress upon disposal (*disposal conditions*); and (b) the extent of any fossil-resource savings resulting from the use of CO<sub>2</sub> as a carbon feedstock in the manufacturing process (*savings of fossil resources*), were predictive. Furthermore, where personal health risks (*perceived health complaints*) were introduced and considered by participants, it was these considerations that became the most decisive factor in shaping acceptance.

While most research in this area has, to date, been qualitative—appropriately recognising the challenges of assessing lay-public perceptions of unfamiliar subject matter (e.g. assessing *pseudo-opinions*, see Section 2.1)—recently larger, quantitative surveys have also begun to emerge. For instance, Perdan et al. [37] conducted a survey on 1213 UK adults to establish the extent of awareness and acceptance of CDU (in this case referred to as CCU). This study illustrated the very low-level of public awareness about the technology (only 9% were confident they knew what the technology was); simultaneously highlighting both the challenge and opportunity for proponents of the technology in securing public acceptance.

### 1.3. The current study

While there is growing interest in understanding lay-public perceptions of CDU (and affiliated product options), there still exists a paucity of published research in this field (see [5]). The current study sought to address this gap by providing an exploratory investigation of opinions about CDU within a convenience sample of interviewees from the UK and Germany.

Twenty-eight in-depth, qualitative interviews were conducted with lay-people in Sheffield, United Kingdom ( $n = 18$ ) and Potsdam/Berlin, Germany ( $n = 10$ ) between July 2014 and December 2015. The aim was to elucidate more about emerging perceptions of CDU in these countries, using the *concept*, *technical* and *societal consequence* themes identified to previous research as a framework for the analysis (see [6]).

Due to the fact that CDU facilities can be affiliated with CCS operations (e.g. [2]) we were also able to investigate how extant public opinion about CCS in each country shaped interviewee’s opinions about

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