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Carbon capture, utilisation and storage scenarios for the Gulf Cooperation Council region: A Delphi-based foresight study

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ABSTRACT

Capture, utilisation and storage of carbon dioxide resulting from combusting fossil fuels is gaining attention around the world as a means of addressing climate change. This paper aims to present a set of carbon capture, utilisation and storage (CCUS) scenarios for the hydrocarbon-rich Gulf Cooperation Council (GCC) region through to the year 2030, with the ultimate goal of stimulating constructive debate and discussion at both policy and academic levels. This will also be beneficial in terms of identifying future opportunities and threats so that better-informed policy action can be taken today. Four explorative scenarios have been developed using the Delphi technique, and they represent a joint creation of about one hundred highly-informed individuals from diverse professional backgrounds.

1. Introduction

In recent times, ample revenues from exporting hydrocarbons have fuelled the apparent wealth of the members of the Gulf Cooperation Council (GCC), which is comprised of the Kingdom of Saudi Arabia (KSA), the Kingdom of Bahrain, United Arab Emirates (UAE) and the states of Kuwait, Oman and Qatar. It is notable that with ownership of approximately 40% of the world's proven oil reserves and around 25% of natural gas reserves [1], the GCC countries contributed to approximately 8% of the world's carbon dioxide (CO_2) emissions in 2009 [2]. Over the past few years, countries in the GCC region (in particular the UAE, KSA and Qatar) have been identified as being the world's largest per capita emitters of CO_2 [3]. One of the most pressing challenges facing GCC policy-makers is the need to address a rapidly increasing demand for domestic energy – which is a direct result of swift growth in both population and industrial development – in a carbon constrained manner. To this end, the carbon capture, utilisation and storage (CCUS) technology appears to be a promising solution. The CCUS process involves the capture of CO_2 from stationery sources, which is then transported via pipelines or ships for injection into either suitable rock formations (for long-term CO_2 storage) or aging oilfields (to enhance the oil production, i.e. a process commonly referred to as Enhanced Oil Recovery 'EOR') [4]. At the moment, the GCC countries rely on natural gas in their EOR operations. By using CO_2 instead, freed natural gas would then be of more value to these countries when it is either sold on international energy markets, or used as a 'relatively clean' fuel to meet rapidly increasing domestic energy demand.

Despite the apparent benefits, CCUS activities are still in their infancy in the GCC region. For example, Qatar has recently started extensive research and development programmes, with the ultimate aim of deploying EOR-CO_2 operations for the Al-Shaheen field. Similarly, the KSA has recently announced plans to carry out an EOR-CO_2 demonstration project by the year 2013, whereby 40 million standard cubic feet will be injected per day into the Ghawar field [5]. Moreover, Abu Dhabi – the capital city of the UAE – has started the development of a large scale CCUS networks since 2007. The current plan is capture

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5 MTPA (i.e. Million Tonnes per Annum) by 2014–2017, and a total of 30 MTPA by 2030. It is perhaps worth noting here at the first EOR-CO_2 pilot study was conducted at the Rumaitha field in the UAE, with the announced aim of understanding the behaviour of CO_2 in the heterogeneous carbonate oil-bearing reservoirs before commencing full-scale development [6].

On the global front, four industrial-scale CCUS projects are currently in operation, namely Sleipner and Snøhvit projects (in Norway), Weyburn-Midale (in Canada) and Salah (in Algeria). Van Alphen et al. [7] documented several other projects which are still in the pilot phase, and acknowledged some of the challenges that are currently facing CCUS endeavours such as lack of financial viability and political support, non-existence of a supportive regulatory framework to oversee CCUS activities, in addition to technological challenges including energy penalties for industrial facilities when retro-fitted with CO_2 capture technologies.

Given the limited research on the prospects of CCUS in hydrocarbon-rich countries, this paper presents a set of plausible CCUS future development scenarios for the GGC region by means of the Delphi technique. The ultimate aims of this paper are twofold: (i) to provide food for thought and stimulate constructive discussion in both academic and policy-making circles on the factors perceived as being critical for promoting CCUS endeavours; (ii) to explore potential opportunities and challenges that could affect the future deployment of CCUS activities in the GCC region.

In the next section, an overview of the Delphi methodology is provided. Following this, we discuss the design of this foresight-orientated study and the development of CCUS scenarios framework. We then explain the scenarios' narratives (i.e. qualitative assumptions) and present their quantitative implications. The paper ends with suggestions on possible future research directions that emerge from this study.

2. Delphi-based foresight scenarios: an overview

Foresight scenarios can be defined as holistic images of the future, or representations of possible alternative futures. Scenarios have been extensively used around the world as a planning tool to explore new grounds and generate new ideas, to challenge conventional views and focus on the most important uncertainties facing a particular subject of enquiry [8,9]. In the field of energy, a large number of scenarios have already been developed. Recent examples include those developed in the UK [10], Canada [11], the United States of America [12], KSA [13] and for the whole world [14,15]. Since energy infrastructure projects usually take a very long time to build, most energy scenarios tend to adopt a very long-term perspective, i.e. looking ahead at least twenty years.

Developing such scenarios, which usually incorporate a narrative (i.e. storyline) element and a modelled quantitative section, involves both rational analysis and subjective judgment. In this regard, it is often recommended that the scenarios be developed by using interactive and participatory methods, where potential users of the scenarios contribute in their generation and evaluation [16]. One of the most commonly used methods to develop scenarios is known as the Delphi technique, which is a systematic and interactive method for eliciting and collating informed judgments on complex matters where precise knowledge is not available. The Delphi process usually involves circulating a series of sequential questionnaires (or Delphi rounds) to a panel of experts on the subject under consideration, with each Delphi round building on the results of the previous one [17–20].

There appear to be some concerns associated with the Delphi approach that are worth noting. First, there is lack of consensus regarding the ideal size of a Delphi panel. For example, Turoff [21] suggested a suitable panel size of between ten and fifty, whilst some scholars [e.g. 22,23] proposed an optimum panel size of twelve people, or a minimum of seven panellists [24]. The latter noted that whilst many pioneering studies used very small panels, some Delphi panels also comprised a few hundred and, in one case, several thousand people. However, assuming that 'two heads are better than one', one could presume that the more participants there are in the Delphi panel, the better [25]. Nonetheless, more emphasis should be placed upon the qualities, expertise and relevance of the Delphi panellists as opposed to their number, as the latter tend to be influenced by factors that are more related to the scope and resource constraints of the study in hand [26,27]. Clearly, since the outcome of the Delphi study is largely dependent upon the composition of the panel, it is essential that the expert panel be appropriately selected. Here, it is worth highlighting a second source of debate in the Delphi literature, specifically on the definition for the term 'expert'. In this regard, Goodman [28] argued that "it would seem more appropriate to recruit individuals who have knowledge of a particular topic and who are consequently willing to engage upon it without the potentially misleading title of 'expert'" (pg. 732). This is important since quite often, some Delphi panellists drop out during the study. Bearing in mind that no new experts should be invited to participate half-way through the study, an aim should be that attrition rates should be kept as low as possible [29,30]. Hence, it might be reasonable to suggest that the participants' commitment is directly related to their interest, as well as to their potential involvement with the issue addressed in the Delphi study. In addition, one success factor for Delphi studies appears to be the heterogeneity of the panellists. It is believed that such diversity ensures a wide spectrum of opinions and judgements, thereby reducing potential sources of bias [31]. In addition, it is important to ensure the anonymity of the experts during the study in order to reduce the bias that could be introduced if the responses were influenced by peer pressure within the group [28].

3. Delphi study design

In this study, the Delphi panel was comprised of 100 highly informed members from a diverse range of backgrounds. The panel included professionals from industry and academia in addition to government officials. Therefore, the developed