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Business Models for Carbon Capture and Utilization: A case study in Finland

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Abstract

An important technology now being assessed to support decarbonization goals is CO_2 capture, utilization, and storage (CCUS). CO_2 capture technologies can reduce emissions from industrial processes and power generation by up to 90%. In this study, we review the main components of business models and emphasize the key area to be emphasized when developing a CCUS business model. A business model for CCUS application should be distinguished at the value proposition stage for the three archetypes (resource recovery, green growth, low carbon grid).

The results of the study indicate that there is a possible overlap between the value propositions of CCUS projects. A successful business model needs to highlight the value proposition in terms of value creation and delivery in CCU solutions in specific industries. This would ensure consistent comparison across the global studies.

Keywords: carbon capture; utilization and storage; business model

Introduction

The role of CO_2 capture, utilization, and storage is recognized as a key option in reducing greenhouse gas emission (e.g. Ku et al. (2020). Carbon dioxide (CO_2) utilization is a critical component of Finland's strategy to reduce greenhouse gas emissions and transition to a more sustainable energy system. Most of the industrial related CO_2 emissions from Finland originate from biogenic sources and is suitable for CCU utilization. CO_2 utilization (CCU) technologies can convert captured CO_2 into fuels, chemicals, and other products, reducing the need for fossil fuels and creating new markets for carbon dioxide. Despite these potential benefits, CCUS technologies face a number of challenges and barriers for deployment, including high capital costs, regulatory uncertainty, public acceptance and lack of business models (Muslemani et al., 2020; Nagireddi et al., 2023; Onarheim et al., 2015). As there are no suitable geological storage sites in Finland for CCS application, there is a growing need to explore viable business models for carbon capture utilization. Research on CCU has focused on capturing and utilization technologies, with little research on business models and development (Saarinen et al. 2024). Muslemani et al. (2020) identified that one of the most fundamental reasons why CCUS is not an established technology in industrial sectors, is that there is yet to be defined concrete business models for the operation of CCU utilization. A knowledge gap exists in identifying the most important elements driving success in industrial CCUS business models. In this study, we review the main components of existing business models and present a case study of carbon capture utilization in Finnish energy and process industry with emphasis on value propositions. The paper is structured as follow. Section 2 describes the methodology, and results and conclusions are discussed in Section 3.

2. Methodology

2.1 Business Models and CCU

Literature presents several definitions of business models (Richardson, 2008; Johnson et al., 2008; Osterwalder et al. 2011). A business model is different from a financial model of a business. It outlines the ways that the company satisfies customer needs, attracts customers to pay for their product or service, and generates revenues from customer payment (Li et al. 2019). In this paper we adopted the definition of Osterwalder and Pigneur (2011) who defined that a successful business model consists of nine building blocks, including customer segments, value proposition, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure. The nine building blocks form the key platform of a business model canvas. In this paper, we focus on the value proposition component, since different value proposition of the business model would determine the various drivers, technical and policy requirements of the business model canvass.

Ku et al. (2020) identified three value propositions for CCUS business model: (i) *resource recovery* focuses on the management of carbon in the production of hydrocarbon resources, primarily the removal of CO_2 from natural gas extraction and the use of CO_2 in enhanced oil recovery operations; (ii) *green growth* emphasizes CO_2 reductions in support of climate action, using CCUS to reduce the carbon footprint of economic activity, and (iii) *low carbon grid* development focuses on the value of CCUS in supporting grid scale energy storage.

2.2 CCU Utilization in Finland

In Finland, the largest industrial sector that emits CO_2 is pulp and paper production. The emissions from the sector were over 20 $MtCO_2$ in 2020. This was followed by the power and heat production and waste- to- energy power plants. Most of the emissions from the energy industry were fossil in 2020, however, biogenic emissions were over 5 $MtCO_2$ (Kujanpää et al. 2023).The number of large combustion facilities was 39 in 2020, making them the key point source of CO_2 in Finland, one facility emitting approximately 0.4 $MtCO_2$ per year on average (Kujanpää et al. 2023). CCU utilization projects with major actors in the Finnish energy and process industry and their value propositions are shown in Table 1. Most of the CCUS projects in the energy and process industries focus on green growth and low carbon grid.

Table 1. Value propositions of CCU projects in Finland

Actors	Value Proposition	Application	Deployment stage
Westenergy	Green growth	CCU for power-to-fuels (P2X) to produce carbon neutral transportation fuels.	Advanced stage
Fortum	Green growth	Research on plastics CCU using CO2 from WtE plants.	Early development
Keravan Energia Oy	Low carbon grid	Piloting and feasibility of power-to-gas in a biomass-fired power plant.	Advanced stage
Turun Seudun Energiantuotanto Oy	Green Growth	Feasibility of a hydrogen and power-to-X plant to produce fuel for heavy road and marine transport.	Construction
Neste – SHARC project	Green Growth	CCS and hydrogen production at the Porvoo oil refinery.	Advanced Stage

Adapted from Kujanpää et al. 2023. Early development, the facility has completed a pre-feasibility study. In construction, a positive final investment decision has been reached. Advanced development, the facility is completing or has completed front end engineering and design. Operational, CO_2 is being actively captured, transported, and stored (Global Status of CCS 2024).

2.3 Case Study

The case company is Westenergy and is selected due to its advanced deployment stage. Westenergy operates within circular economy and is located in the city of Vaasa (northwestern area of Finland). The company operates a modern waste-to-energy plant where non-recyclable sources separated from combustible waste is refined into electricity, heat and recovered materials. Currently the company produces about 60 % of the district heating needed in the Vaasa region. Annually, approximately 200 000 tonnes of waste is refined into electricity, heat and renewable materials in Westenergy's Waste-to-Energy plant, and 180 000 tonnes of CO_2 is emitted. By 2027, the company is planning to commission one

of the first full scale carbon capture plants in connection to a waste-to-energy plant. The unit will capture CO_2 from the flue gas generated by the existing waste power plant. The captured CO_2 will be liquefied, and a large fraction will be transported to Kristiinankaupunki where it will be utilised at Prime Capital´s and CPC´s power-to-x site. A summary of the carbon capture operations of Westenergy is presented in Figure 1. As shown in Figure 1 below, the value proposition for Westenergy is e-fuel and permanent carbon products (green growth), and recycling and storage for value added product (green growth). This requires the development of a business model for supply of CO_2 to develop e-fuel, and for carbon recycling and storage for high material efficiency.

Figure 1. Value proposition of Westenergy

3. Results and Conclusion

Developing a single business model for CCU is not possible as one size does not fit all. CCU business models should be distinguished at value propositions (resource recovery, green growth, low carbon grid). Our results indicate an archetype of CCU deployment with the same value proposition having different technical imperatives and customer segment. This requires more studies on business model cases. In addition, our study shows that e-fuels and renewable energy plastics are potential areas for CO_2 utilization in Finland. E-fuels presents a promising alternative for reducing emissions in heavy transport, while the carbon tax policy requires careful balancing to ensure social welfare. Different value propositions of CCU utilization would require different key drivers, and channels. A successful business model of CCU needs to consider technology requirements, and policy requirements, among others. Overall, a comprehensive and integrated approach, supported by robust political frameworks, is essential for effective CO_2 utilization in Finland.

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