The Nexus of Public Perceptions of Contemporary Energy Technologies in the Face of Climate Change

by

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A thesis submitted in partial fulfilment of the requirements for the degree of

Master of Science

in

Agricultural and Resource Economics

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Abstract

The pressure to achieve net-zero CO_2 objectives has heightened the need to evaluate energy technologies in Canada, where the oil and gas industry remains essential to the economy. Carbon capture and storage (CCS) is a component of Canada's net-zero CO_2 strategies and can absorb up to 90% of the CO_2 emissions from major point emitters. However, public perception and support for CCS remain controversial. Hydraulic fracturing (HF), on the other hand, is a non-conventional method of extracting oil and natural gas, with growing public concern about its impact on environmental quality and human health. This study investigated the reasons for the heterogeneity in acceptance and support for CCS and HF in Canada. Random effects and latent class models were applied to vignette experimental data to investigate the public's perceptions of CCS as a climate mitigation technology and HF, respectively. Our findings indicate that cross-border import of CO_2 for storage has a strong effect on the acceptance of CCS plant scenarios. Consultation, compensation, proximity, knowledge, risks, and trust are key drivers of CCS acceptance. Public perceptions of HF have also varied. Economic benefits to the community, citizen consultation on HF, proximity, and the likelihood and severity of HF-induced seismicity had the largest effects on individuals' support (ratings) for the proposed HF projects. Supporters of HF tend to be men living in rural areas who have a high level of education and knowledge about the energy sector, whereas HF protesters tend to be college-educated women who are worried about the negative effects of HF. The study concluded that communication efforts to improve public understanding and acceptance of CCS should focus on demystifying the risks of CCS instead of its technicalities and climate mitigation capacity. In addition, prioritising local firms and services in contracts and providing compensation directly to affected individuals can lead to greater public support for HF projects.

Preface

This thesis is an original work of Abdul-Hamid Mohammed. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name: "Effective monitoring of long-term site stability for transparent carbon capture and storage hazard assessment (ENSURE)," number Pro00123473, September 27, 2022. Part of this thesis forms part of a research collaboration led by Professor Ulf Liebe at the University of Warwick, Dr. Juergen Meyerhoff at HWR Berlin, and Professor Mirko van der Baan at the University of Alberta, with Professor Sven Anders being the lead investigator at the University of Alberta. The survey design and data collection on HF in western Canada (which is used for the paper in chapter 2) were done by Jordan Phillip. The survey and experimental techniques referred to in chapter 1 were designed by me with the assistance of Professor Sven Anders and Nimanthika Lokuge Dona. The literature reviews, data analysis, and concluding remarks are the original work. As of this writing, no part of this thesis has yet been published.

Dedication

In loving memory of my father, who passed away six months into my programme.

To my mom, siblings, and wife for your love and support

Thank you.

Acknowledgments

I would like to express my sincere appreciation to Professor Sven Anders, my supervisor, for the unwavering support and guidance provided during this research. Your kindness and encouragement have been invaluable. I would like to express my gratitude for the opportunities you provided during my graduate studies. Your support has allowed me to pursue extracurricular activities and explore my academic interests, which have been invaluable for my academic career. Thank you for your generosity and guidance. This piece would not have been completed without your agility in responding to emails and requests. Thank you for your kind and supportive words.

I would like to express my gratitude to Mrs. Nimanthika M. L. Dona, a colleague and PhD student, for her valuable support and guidance during this study. Your support was instrumental in helping me stay focused and meet deadlines. I would also like to thank my exam committee, Professor John Parkins (chair), Professor Feng Qiu (arm's length), Professor Mirko van dan Baan (co-supervisor), and Professor Sven Anders (supervisor), for taking their time to review my work and provide valuable insights. Finally, I would like to express my gratitude to the esteemed faculty and staff of the Resource Economics and Environmental Sociology (REES) department for their invaluable assistance and guidance, which have greatly facilitated the academic pursuits of graduate students.

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List of Acronyms and Abbreviations

AIC	-	Akaike Information Criterion
BIC	-	Bayesian Information Criterion
CAPP	-	Canadian Association of Petroleum Producers
CCA	-	Council of Canadian Academies
CCS	-	Carbon Capture and Storage
CCU	-	Carbon Capture and Utilisation
CCUS	-	Carbon Capture, Utilisation and Storage
CE	-	Choice Experiment
CICC	-	Canadian Institute for Climate Choices
CO_2	-	Carbon dioxide
DEC	-	Department of Energy Conservation
DIF	-	Differential Item Functioning
DOE	-	Department of Energy
EU	-	European Union
FSE	-	Factorial Survey Experiment
GHG	-	Greenhouse Gas
H_2O	-	Water
H_2S	-	Hydrogen Sulphide
HF	-	Hydraulic Fracturing
IEA	-	International Energy Agency
IPCC	-	Intergovernmental Panel on Climate Change
LC	-	Latent Class

LCA	-	Latent Class Analysis
LCM	-	Latent Class Model
LL	-	Log-likelihood
NAS	-	National Achievement Survey
NETL	-	National Energy Technology Laboratory
NGO	-	Non-governmental Organisation
NIMBY	-	Not In My Backyard
PC	-	Principal Component
PCA	-	Principal Component Analysis
VE	-	Vignette Experiment
VLMR	-	Vuong-Lo Mendell-Rubin
WCSB	-	Western Canadian Sedimentary Basin

Chapter One

Public Perceptions and Acceptance of Carbon Capture and Storage for Greenhouse Gas Mitigation: A Random Effects Model

1.0 Introduction

According to the International Energy Agency (IEA), global energy-related carbon dioxide (CO_2) emissions experienced a notable increase in 2021, surpassing a total of 36 billion metric tonnes (IEA, 2021a). Over the last decade, the output of other heavy-point greenhouse gas emitters, including steel, cement, and fertiliser, has also grown exponentially. Despite the continued need for these materials to keep our agricultural, construction, and transportation sectors afloat, continuing down this road is a potential recipe for global disasters. Rapid decarbonisation is crucial for the world's average temperature to rise by no more than two degrees Celsius above pre-industrial levels and to avert the worst effects of climate change (IPCC, 2022; Rockström et al., 2017).

Challenges caused by climate change have prompted a plethora of responses from a wide range of disciplines. In the technology industry, Rolnick et al. (2019) suggested leveraging machine learning to assess climate-related data collected through satellites. Economists have proposed a variety of measures to make the emission of CO_2 and other greenhouse gases (GHG) more expensive (David & Herzog, 2000; Nordhaus, 2019). In the biotechnology industry, Tylecote (2019) advocated the use of biomedicine and plant breeding to reduce global warming. Within the construction industry, Röck et al. (2020) conducted a large-scale analysis of more than 650 buildings to quantify the effect of embedded GHG emissions and advocated for shifts in building designs and operations. Other options to mitigate the impacts of climate change include leveraging wind and solar energy, planting more trees, adjusting food consumption patterns, and direct air capture of CO_2. However, while a variety of strategies may be implemented to lessen the severity of the effects of climate change, most of them are either inadequate, not ready, or too expensive.

GHG removal and sequestration technologies are gaining interest as potential decarbonisation solutions that may be used in tandem with emission reductions (Pianta et al., 2021). Many of these decarbonisation solutions, aimed at reducing the effects of climate change and increasing people's ability to adapt to it, have received considerable research and development. However, several questions remain unanswered. To minimise emissions of GHG, carbon dioxide capture and geological storage (CCS) is widely considered to be a viable, expedient, and secure option (Sun et al., 2021) and has become a vital component of national and international efforts to curb emissions of GHG (Scott et al., 2013). CCS has emerged as a promising technique in the fight against climate change, with the potential to absorb up to 90 percent of the CO_2 emissions from fossil fuel power stations and other industrial heavy point-emitters (Kahlor et al., 2020). The goal of this technique is to prevent CO_2 from being released into the environment because of the combustion of fossil fuels, such as coal, petroleum, and natural gas, and burying it beneath permeable rocks where it cannot escape into the atmosphere (Figueroa et al., 2008; Leung et al., 2014; Parson & Keith, 1998). More than 200 million metric tonnes of CO_2 have been removed from the atmosphere using this technology since the 1970s (Gibbins, 2019). Without CCS, mitigation costs are confirmed to increase by an average of 138%, according to reports (IEA, 2021b).

While interest in CCS has grown in the scientific community and gained attention from organisations and governments worldwide (Rosa et al., 2021), public perception and support for the technology remain controversial. Yet, it must be emphasised that public support is crucial to the ultimate success of CCS (Wang et al., 2021). Although the safety of CCS has been proven in several studies (Ringrose et al., 2017; Ringrose, 2018), according to Gabrielli et al. (2020), the primary barriers to realising the net-zero-CO_2 objective through CCS technology are the accessibility, availability, and acceptance of CO_2 storage facilities. CCS has been around for a while in the industrial world, yet most individuals are still unaware of what it is (Xenias & Whitmarsh, 2018). The absence of public support and the difficulties of implementing CCS in communities have both contributed to the postponement or outright cancellation of some CCS programmes (Witt, 2019).

Critics of CCS claim that it is only a lifeline that helps the oil and gas sector to keep running, and that if the goal is to reduce emissions, then we ought not to be discussing how to store CO_2 so much as we should be looking at ways to prevent it from occurring in the first place (Gonzalez et al., 2021). Induced seismicity, dangers associated with CO_2 transport, and the potential for CO_2 leakage are other significant concerns about the CCS technology (Lokuge et al., 2023). Proponents of CCS, however, argue that decarbonisation through capture and storage is the safest, expedient, and secure approach since we do not have the luxury of time to progressively phase out high-emission industries without causing socio-economic instability. CCS has become an essential and integral component of the decarbonisation pathways of nations like Canada, the US, and the EU as they face increasing urgency to fulfil their net-zero CO_2 commitments.

Public opinion and assessment of CCS projects have been the subject of many studies (Boyd et al., 2017; Gough & Mander, 2019; Moon et al., 2020; Pianta et al., 2021; Upham & Roberts, 2011). When new technologies emerge with the potential to reduce GHG emissions, it it important to comprehend the public's acceptance of these innovations and the regulations that will either encourage or stifle their development (Moon et al., 2020). The public's opinion of CCS is as important as the technology's potential as a component of global plans to reduce GHG emissions and slow global warming (Arning et al., 2019). The rate at which this technology may be commercialised, and the overall cost of energy generation are also directly affected by CCS's implementation (Wilberforce et al., 2021).

As with other contemporary energy technologies (such as hydraulic fracturing), CCS has become a divisive topic due to several ongoing debates both in literature and policy. The increasing political obstacles associated with achieving emission reductions at a rate that is considered reasonable heighten the urgency of discussions on CCS as a means of achieving net-zero CO_2 targets (Carton et al., 2020). Initial efforts to implement CCS, spurred by the G8's 2008 decision to increase international collaboration on CCS and aim to start 10 large-scale CCS demonstration projects by 2010, did not materialise on the scale that was needed (Martin-Roberts et al., 2021). Owing to the complexity of the social, political, economic, and public aspects involved, the success of CCS cannot be reduced to engineering alone (Lima et al., 2021).

For widespread adoption of CCS, a paradigm shift of unprecedented proportions is likely necessary. According to experts, society will eventually need to regard CO_2 as sewage waste and demand that companies pay taxes or levies for its capture and disposal (Lackner & Jospe, 2017). In Canada, this paradigm shift is still in the distant future, as public awareness, support, and acceptance of CCS remain rather low (Boyd et al., 2017; Seigo et al., 2014; Steeneveldt et al., 2006; Tcvetkov et al., 2019). There is also the possibility of induced seismicity, which has been shown to significantly influence people's willingness to adopt subsurface technologies (Evensen et al., 2022; Haemmerli & Stauffacher, 2020; Lokuge et al., 2023). However, the impact of induced seismicity, defined as seismic events caused by human activities, has not been well considered in discussions on CCS.

The purpose of this paper, therefore, is to evaluate public perceptions and acceptance of CCS as a climate-mitigation strategy from a socio-psychological perspective using a vignette experimental technique. This distinguishes this paper from the wealth of public perception studies of CCS conducted in Canada and throughout the world. While stated preference techniques tend to focus on individuals' preferences, vignette experiments highlight the significance of societal norms and informal conventions when assessing conventional energy sources (Parkins et al., 2021). Thus, with the use of vignettes, people are able to contemplate alternative methods of building energy systems while keeping in mind the broader social, economic, and environmental settings.

Regardless of this novel aspect, and in line with growing efforts to diversify research on public involvement in the advancement of emerging technologies (Bellamy et al., 2019; Bellamy & Lezaun, 2017), it is critical that this paper be viewed within the existing larger ecology of investigations into the public licencing of unconventional decarbonisation alternatives. Public trust, knowledge, risk, and perception of CCS in relation to its unique impact on induced seismicity are currently understudied. This paper, therefore, seeks to examine individuals' perceptions of the seismic risks associated with CCS and the potential impacts of alternative monitoring strategies (technical and regulatory) on the public acceptability of CCS.

The remainder of the paper is structured as follows: section two examines the technical aspects of CCS as well as the body of literature on public perceptions of CCS. The third section examines data and techniques. The fourth section contains the findings and discussions. The fifth section wraps up the study and offers policy recommendations.

2.0 Literature Review

The effects of climate change are increasingly felt by both humans and animals. Economic losses have resulted from the adverse effects of climate change on society, notably floods, rising temperatures, and wildfires (NAS, 2021). Human activities have contributed to the warming of the atmosphere, oceans, and land (IPCC, 2021). According to Brauers and Oei (2020), CO_2 and other gases released during coal combustion have the greatest impact on global warming. As estimated by the IPCC (2021), human activity is estimated to increase global temperatures by between 0.8 and 1.3 degrees Celsius between 1850-1900 and 2010-2019, with a current estimate of 1.07 degrees Celsius.

Temperatures in Canada are predicted to continue to increase as a result of growing national and global emissions (CCA, 2019). Prompt and decisive action is needed, given the collective commitment of 174 nations, including Canada, to mitigate the release of GHG and attain carbon neutrality by the year 2050 (Rubin, 2016). The Canadian Climate Change Commission has indicated that being carbon neutral by 2050 is an achievable goal, with several potential pathways (CICC, 2021). Reducing GHG emissions, switching to solar and wind energy, using electric vehicles, changing dietary patterns, and using geoengineering to vary the amount of heat radiation reaching the Earth's surface are all viable strategies for climate mitigation (Weyant, 2017). The pressing need to reduce emissions and address the global impacts of climate change necessitates the prompt implementation of collaborative and economically efficient climate-mitigation strategies.

CCS technology has been identified as a rapid and economically viable decarbonisation strategy and has been incorporated in many integrated assessment models for future energy systems (Capellán-Pérez et al., 2020; IPCC, 2018; Koelbl et al., 2014). It demonstrates, in a very convincing manner in most of the possible outcomes, the urgent need to implement carbon emission reduction technologies such as CCS (Holz et al., 2021). Most of them, however, stress the need for rapid education in order to simplify and expand CCS implementation from a "top-down" perspective (Longa et al., 2020). Top-down assessments are useful for obtaining a bird's-eye view of the entire picture, however, as noted by Holz et al. (2021), they always leave out important considerations on the social, economic, and technological aspects of CO_2 capture, transportation, and storage. This strategy for accelerating the rollout and growth of CCS projects did not lead to an increase in public acceptance of CCS, despite its technical breakthroughs (Ashworth et al., 2019). Considering the significant role of CCS technology in recent years as a viable solution for addressing climate change, several surveys have been conducted to evaluate its level of public acceptability (Braun, 2017; Gibbins, 2019; Gonzalez et al., 2021; Saito et al., 2019; von Rothkirch & Ejderyan, 2021).

Many experts in academia, industry, and politics see CCS as a technological solution that can help lower GHG emissions and guarantee a steady energy supply (IPCC, 2018). Capturing CO_2 emissions at their sources, such as power plants or factories, and permanently storing them in underground reservoirs is known as CCS (Alphen et al., 2010). There are additional cases where the captured CO_2 is used in the production of other goods; in these cases, the process is known as "carbon capture and utilisation" (CCU) (Gough & Mander, 2019). Some studies suggest using the collected CO_2 for enhanced oil recovery (Whitmarsh et al., 2019), whereas others advocate the use of the collected CO_2 as a feedstock for industrial operations (Bruhn et al., 2016). Together, CCS and CCU are often referred to in the literature as carbon capture, utilisation, and storage (CCUS) (Osazuwa-Peters & Hurlbert, 2020; Pianta et al., 2021; Wang et al., 2021).

International studies have consistently revealed that the public is inexperienced with CCS technology compared to all other emission reduction technologies (Ashworth et al., 2019; Lima et al., 2021; Upham & Roberts, 2011). Large-scale CCS in rock formations was first attempted offshore in Norway in 1996 and onshore in Algeria in 2004 to minimise atmospheric pollution levels (Steeneveldt et al., 2006). Since then, the technology has moved across nations and gained traction, with several organisations pledging financial support for its advancement. To aid in the construction and operation of CCS plants, among other things, the EU has set up a €10 billion Innovation Fund (Rycroft, 2020). To advance CCS technology internationally, the Norwegian government has allocated approximately 20% of its research and development budget to foreign requests for collaboration (Stangeland et al., 2021). Developing CCS technology is a priority for the US Department of Energy (DOE) (Alphen et al., 2010), and since 2003, it has helped advance a wide range of CCS technologies (NETL, 2007). Canada, the US, and the UK have committed 3.4 million Canadian dollars to CO_2 injection into deep coal seams (Steeneveldt et al., 2006).

Currently, there are 15 large-scale CCS projects running worldwide, and an additional seven are in the planning stage (Ringrose et al., 2017). Over the last 20 years, significant advancements have been achieved in the field of CCS, particularly in terms of technological feasibility and safety measures, thus enhancing its practicality and suitability (Edwards & Celia, 2018; Lackner & Brennan, 2009; Wilberforce et al., 2021; Zhang et al., 2022). It is anticipated that CCUS will generate employment far beyond 2030, at a competitive rate with the oil and gas industry (Gupta & Sen, 2019). However, the public's reaction to CCS operations remains uncertain, and opposition may lead to delays or cancellations of CCS projects (Federico d'Amore et al., 2020).

The health, safety, and sustainability of communities and ecosystems are intertwined with the logistics of transporting dangerous items (Holeczek, 2019; Merk et al., 2022). In particular, in terms of health risks and the cost of spillovers, it is becoming more crucial to measure and manage environmental effects and human health concerns on a global scale (Dehghani-Sanij et al., 2019). It is feasible that the geological subsurface, with its storage capacity, can be used to permanently store CO_2 on a daily to seasonal basis (Bauer et al., 2017). While this is true, it is essential to remember that little research has analysed how people feel about CCS in relation to actual or proposed CCS storage sites (Braun, 2017; Saito et al., 2019).

According to Boyd et al. (2017), incidents that might occur because of CCS include, among other things, CO_2 leakage that could negatively affect neighbouring communities or animals. Sensations, technical terms, and attitudes that have little to do with the technology itself impede the implementation of CCS as climate mitigation technology (Peridas et al., 2021). These considerations, if understood and reconciled, might improve our understanding of CCS (Osazuwa-Peters et al., 2020).

In a representative Swiss mail survey among laypeople, Wallquist et al. (2010) noted that non-technical issues such as socioeconomic concerns were shown to have a greater impact on the risk and benefit perceptions of CCS. Using a series of discussions, Shackley et al. (2004) stated that ambiguities around the possible dangers of CCS were of great concern to many, specifically the risks of accidents and leakage. However, through a stakeholder survey, Liu et al. (2012) concluded that the majority of those surveyed did not believe that the dangers of CCS were significant. The public's adoption of technological innovation is influenced not only by the technology itself, but also by a wide range of social and cultural elements (Rothkirch et al., 2021). Oltra et al. (2010) found that people tend to see the dangers of CCS as more important than the risks of climate change, which they regard as far away in time and place. Where risk perception is high, ambiguity regarding critical information is often a significant factor influencing CCS acceptance

(Wennersten et al., 2015). According to assessments made by experts, the occurrence of significant CO_2 leakage, which might potentially lead to detectable environmental or public health consequences, remained consistent throughout three distinct time intervals, and was estimated to be roughly 1 in 103 (Larkin et al., 2019). However, CO_2 leakage and induce seismicity continue to be major determinants of public support for underground energy technologies (Krause et al., 2014; Lokuge et al., 2023).

Policy analysts in Canada and the US continue to factor in the social cost of carbon when considering the advantages of CCS in reducing CO_2 emissions. If the monetary value associated with the negative impacts of carbon emissions on society exceeds the financial investment required to prevent the release of one metric tonne of CO_2 into the atmosphere, it may be seen as passing a cost-benefit analysis. In a study conducted by Heyes & Urban (2019), they noted that the costs associated with the large-scale deployment of CCS outweigh its benefits. A good understanding of the potential for cross-border trade of CO_2 is expected to offer a novel lens through which to examine the cost-benefit analysis of CCS both domestically and internationally.

People's views on the potential risks and benefits of new technologies are influenced by the level of trustworthiness they attribute to their management and implementation (Terwel et al., 2009). The familiarity and trust gained by project leaders over the course of years or even decades of honest work, visible presence, and reliable conduct are crucial to the project's ultimate success (Ferguson & van Gent, 2017). It has been shown that people's level of confidence in systems is positively related to their openness to adopting CCS (Ashworth et al., 2010). To gain public trust in CCS, project developers need transparent rules on site selection, safety criteria, monitoring, ownership, and accountability (Alphen et al., 2010).

According to Arning et al. (2019), trust in stakeholders, especially environmental organisations, influences support for CCS deployment more than industrial stakeholders. While Pianta et al. (2021) observed that strong believers in public think tanks are more inclined to endorse a policy if it receives backing from such organisations. A crucial aspect in determining how people see technology's hazards and advantages, according to Cvetković et al. (2021), is their level of social trust. Using a regression analysis, Ashworth et al. (2019) discovered that those who put faith in the government and CCS corporations to work in the public's best interest, value long-term success over short-term benefits, and value economic growth above environmental preservation are more likely to be in favour of CCS. Boyd et al. (2017), who also used a regression model, found that those who had greater faith in the government were more inclined to support federal investment in CCS technology.

Anghel (2017) discovered, using a regression analysis, that first impressions of CCS are heavily influenced by the extent to which one is versed in environmental problems including climate change. Studies show, however, that public opinion and experience are highly contextualised, and that technical knowledge alone is an inadequate predictor of attitudes, risk perceptions, and behaviour (Burgess et al., 1998; Démuth, 2012; Qiong, 2017). As compared to technical knowledge and accurate assessments of risk, socioeconomic issues, like poverty and inequality, have a far larger influence on people's risk and benefit perceptions of CCS (Wallquist et al., 2010).

In a study conducted by Yang et al. (2016), it was found via the implementation of a structured survey that a majority of the participants (95%) exhibited a lack of awareness about CCS in China. This has been confirmed in another survey by Ashworth et al. (2019) that both China and Australia have low levels of knowledge about CCS. In their survey, Lima et al., (2021) also noted that only about 0.5% of those interviewed in Brazil had a good comprehension of CCS. These results present a divergence from a study carried out in Canada (Boyd et al., 2017), where a greater proportion of respondents said that they were familiar with CCS and had knowledge of its nature or were aware of CCS but lacked understanding of its specifics.

Research shows that public understanding of CCS has not improved substantially over time (Ashworth et al., 2019; Dowd et al., 2012). Because of this lack of knowledge about CCS, the accuracy of data from large-scale surveys has been questioned (Yang et al., 2016). More cutting-edge methods are required for analysing the CCS technology (such as experimental surveys and choice experiments). The first step in becoming an active environmentalist and providing crucial support for climate mitigation technology is having a basic understanding of climate change (Moon et al., 2020), whereas a lack of information may make uncertainty worse (Ashworth et al., 2019). Using in-person field interviews, Lima et al. (2021) observed that urban residents understand that CCS is a way to reduce CO_2 emissions and, as a result, climate change, but climate change is still not as important as other basic services like health, public safety, and job creation. Public perception of CCS might benefit from the expertise of business and non-governmental organisations, which Tcvetkov et al. (2019) found to be highly interested and engaged in CCS progress.

The energy economics literature often explores the evaluation of economic prospects, particularly in terms of local job creation and economic activities. These potentials are generally contrasted with the social (equity) and environmental concerns associated with these technologies (Liebe & Dobers, 2020; Parkins et al., 2021). Studies of opinions have also emphasised the need to consult with and compensate communities impacted by new energy projects (Brennan & Van Rensburg, 2016; Chewinski et al., 2023; García et al., 2016).

Surveys on public perceptions of CCS offer contradictory evidence regarding the impact of socio-demographic factors on acceptance of the technology. A cross country survey by Ashworth et al. (2019) found that in Australia, both age and gender are strong predictors of CCS support, whereas in China, neither factor was significant. The majority of existing research indicates an absence of association between the socio-demographic variables of respondents and their level of support for CCS (Pianta et al., 2021; Tcvetkov et al., 2019). Regarding gender, a survey by Braun (2017) noted that the level of acceptability for CCS is 0.31 points higher among females compared to men. Pianta et al.'s (2021) research, however, found no statistically significant difference between male and female support for CCS. There are also conflicting findings in the literature on the correlation between income and education and CCS support (Ashworth et al., 2019; Braun, 2017; Moon et al., 2020; Pianta et al., 2021).

Despite the useful information that can be gleaned from these studies and the existing public perception literature reviewed, the inconsistencies that have been found empirically highlight the risks of relying on survey research for evaluating public preferences and concerns about a complex issue like CCS. There is a noticeable gap in our understanding of public preferences because the literature does not adequately address cross-border CO_2 trade potentials, local community engagement, compensations, information transparency, different monitoring regimes, or induced seismicity as major benefits and risk factors in individuals' evaluation of CCS. Using empirically designed vignette scenarios, this research conducts a quantitative examination of individuals' judgements of CCS project proposals in Canada, therefore filling a significant gap in the public perception literature on CCS by considering these factors. By employing a factorial survey (vignette) experiment (FSE), we are able to distinguish between the effects of a variety of complex decision factors that enter individuals' evaluation of CCS, including proximity, storage capacity, fairness of consultation and compensation schemes, transparency of CCS risk assessments, cross-border trade of CO_2, and different monitoring regimes (Auspurg & Hinz, 2015a). Inadequate public awareness of CCS, particularly in relation to its safety, effectiveness in mitigating climate change, and risks associated with seismic activity, implies that using a choice experiment may overwhelm participants and thus result in inaccuracies in measurement (Auspurg & Hinz, 2015a; Auspurg & Jäckle, 2017). By using a vignette experiment, we may get around these limitations and have people rate the pros and cons of various CCS scenarios on an ordinal scale, which reduces the likelihood of social-desirability bias (Liebe & Dobers, 2019, 2020).

Observable and unobserved individual heterogeneity may be investigated using a random intercept model. This offset the effects of unobserved heterogeneity across individuals in their ratings of hypothetical vignette scenarios. As noted by Mehdi et al. (2020), more advanced econometric assumptions, including random effects, may be better for studying potential variation in individuals beyond their reported characteristics. Due to the general public's limited familiarity with CCS (Ashworth et al., 2019; Lima et al., 2021), it is contested whether survey data can accurately gauge support or disapproval of a complex energy technology like CCS (Yang et al., 2016). Therefore, evaluating public perceptions within experimentally designed vignette scenarios may enhance our understanding of the intricate dynamics surrounding public support and acceptance of CCS.

The specific objectives of this paper are fourfold: (1) to investigate public perceptions and acceptance of CCS projects, with a focus on the perceived fairness of CO_2 cross-border trading as part of the implementation of CCS; (2) to examine differences in CCS acceptance across respondent socio-demographic and other characteristics; (3) to analyse different governance and monitoring regimes that affect CCS project acceptance; and (4) to assess the impact of perceived

CCS induced seismic/earthquake risks on CCS project acceptance. The consensuses that may be reached from answering these questions will serve as a cornerstone for future discussions in both policy and the literature.

3.0 Data and Methods

3.1 Study Approach

For this research, a factorial experimental survey was conducted in a national online survey administered in October 2022 throughout Canada. The study received ethics approval from the University of Alberta Research Ethics Board (Pro00123473). The 1,002 respondents who filled out the online survey were all part of the same access panel provided by *Survey Engine* – survey software designed for academic research (SurveyEngine, 2023). The individuals were sent an invitation to participate in the survey by means of a hyperlink leading to the survey and vignette experiment. Age, gender, level of education, and household income quotas were established to provide a balanced representation of the Canadian population.

The objective of the survey was to gain a comprehensive understanding of the factors that influence individuals' acceptance of CCS plant scenarios. This includes examining the respondent characteristics that contribute to the acceptance of CCS, as well as their knowledge, trust, perceptions of the risks and benefits associated with CCS, and other relevant environmental factors. This enabled us to assess the public's acceptance of CCS and the extent of its societal approval. The survey (Appendix: CCS Questionnaire and Experimental Designs) included seven (7) sections, presenting each respondent with approximately 30 questions. The sections covered themes and questions relating to the environment, knowledge of different low-carbon technologies, perceptions of different risk factors, trust in different institutions, socio-demographic characteristics, and vignette scenarios.

Participants were shown hypothetical scenarios in which a CCS project was proposed to be built within a certain radius of the participant's home. Seven attributes (factors) were used to define this CCS project and its features, with attribute levels varying across vignettes. Similar to prior qualitative research in this field and political and social debates regarding energy development, the selection of these attributes was driven by theories relevant to distributional and procedural fairness in the energy economics literature (Cox et al., 2020; Liebe et al., 2017; Moon et al., 2020; Parkins et al., 2021). Finally, the research drew on the expertise of people in the CCS and energy industries to build the attributes so that they would accurately represent the most common worries people have about projects of this kind.

3.2 Study Design

When evaluating CCS projects, several factors outside of the attributes of choice experiments (CE) are likely to come into play, including fairness, information transparency, distributive justice, etc. (Cox et al., 2020; Liebe et al., 2017; Parkins et al., 2021). This makes choice experiments less ideal for inferring causal preferences from structurally more extensive social factors (Liebe et al., 2017). As a result, most multifactorial survey studies separate questions concerning social elements, such as people's sense of fairness or justice, their attitudes, or their own social standards, from the actual elicitation of preferences (Parkins et al., 2021).

FSE (also known as vignettes) are an alternative research design that takes into account these societal aspects in condensed and detailed scenarios grounded in important decision-making considerations. The FSE was developed by Rossi and Lazarsfeld in the 1950s as a multi-factor survey technique (Rossi, 1979). FSE has emerged as a powerful tool in the study of social norms and social justice matters since its inception in the 1970s (Auspurg & Hinz, 2015a; Wallander, 2009). In FSE, participants are presented with a series of hypothetical scenarios (called "vignettes") that vary from one another according to a predetermined set of characteristics. After reading each scenario, participants are asked to rate it based on how acceptable, supportive, or fair they find it to be. An FSE is a controlled experiment in which the variables or situational features given in the circumstances are systematically varied, allowing for the isolation of the effects of individual factors that make up the scenario (Liebe et al., 2017). Hence, relevant vignette characteristics and their causal effects may be identified. In addition, theory-led experimental designs and researcher-generated contextual variables allow for the uncovering of causal qualities via the randomization of discrete and interrelated traits, which are assumed to be major predictors of respondents' decision making (Auspurg & Hinz, 2015a). The rating is the dependent variable, and the factors or attributes are the independent variables in multivariate regression analysis.

The following are necessary for any FSE to be conducted successfully: attribute levels and the total number of attributes or features in each scenario must be determined first. The so-called complete factorial, or the total number of scenarios that may be evaluated, is calculated by adding up all conceivable combinations of attributes. Often, the number of scenarios in vignette research will be too high to show to all respondents. Thus, if this is the case, an experimental design is employed to cut down on the sample size of vignettes given to respondents, but it should still be feasible to isolate the influence of individual variables. Researchers must decide on a scale for capturing respondents' ratings (e.g., 5, 7, or 11-point scales are often used). See (Auspurg & Hinz, 2015b, 2015a; Auspurg & Jäckle, 2017) for details.

For the seven different vignette attributes selected, five attributes had three levels and two had six levels (Table 1). First, there has been a substantial discussion in the literature on the possible advantages and discomforts associated with living close to energy plants. More economic activity, employment, and demand for local products and services may result from closer proximity, but this may also lead to more traffic, noise, and rivalry for farmland. People's openness to CCS plants in their communities may be influenced by these nuanced trade-offs.

People exhibit a NIMBY (not in my backyard) effect when they demonstrate a free-rider preference by being in favour of a project conceptually but opposed to it when it is located in close proximity to their own property (Wolsink, 2006). A survey by Krause et al. (2014) found that many Americans were in favour of CCS facility operations as long as they were situated elsewhere in the country but changed their minds when they learned that one would be constructed in close proximity to their homes. However, a national survey in Canada conducted by Boyd et al. (2017) revealed that those who live closer to a CCS facility are more likely to be in favour of such initiatives. In an experimentally constructed situation, these variations increase the possibility of a different outcome. Therefore, the study investigated CCS plant locations and proximity to communities and homes to explore the relationship between proximity and acceptance of CCS project facilities. The proximity of CCS plant locations was modelled, ranging from “less than 50 km from the home”, to “between 50 km and 100km from the home”, and “more than 100 km from the home”.

Table 1: FSE Attributes and Attribute Levels.

Attribute	Attribute Level Number	Attribute Level
Proximity	1	Less than 50 km from the home
	2	Between 50 km and 100 km from the home
	3	More than 100 km from the home
Implementation	1	Group of companies
	2	Government and industry partnership
	3	Federal government
Risk Assessment Information	1	Public will not have access to information
	2	Information available online at the approval stage
	3	Information available as long as the CCS plant is running
Consultation	1	Individuals will not be consulted
	2	Individuals will not be consulted except relevant NGOs
	3	Residents of directly affected communities will be consulted
	4	Residents of directly affected and surrounding communities will be consulted
	5	All residents in the province will be consulted
	6	A national consultation will take place
Benefits	1	No financial benefits
	2	Contract preferences for local businesses in host community
	3	Direct financial compensation to individuals in host community
Storage Capacity	1	5% of total household emissions
	2	10% of total household emissions
	3	20% of total household emissions
Cross-border import of CO_2	1	Only domestic
	2	Domestic and from the Netherlands
	3	Domestic and from the UK
	4	Domestic and from Norway
	5	Domestic and from the USA
	6	Domestic and from Germany

Second, the extent to which the public has trust and confidence in those who will make and supervise critical decisions at a CCS plant may be correlated with their willingness to support the project (Ashworth et al., 2019). This directly translates to the trust the public has in those entities. Publicly administered facilities may be seen quite differently by different people (Cvetković et al., 2021). Some may have a lot of faith in them, while others may consider them inefficient and bureaucratic. In contrast, privately managed institutions may be effective, but their business motives and social benefits are up for debate. Many energy providers are for-profit businesses, so they must be closely monitored and regulated if the public is to get any benefit from their services (Strielkowski et al., 2020). In order to address regulatory concerns with respect to the execution of CCS projects in Alberta, the province has established a government-industry CCS Development Council (IEA, 2008). These connections were modelled into the implementation attribute as “group of companies”, “government-industry partnership”, and “federal government”.

Third, when it comes to siting CCS projects, it's important that the public feels that they have been included, that they have access to relevant information, and that they have a say in the final decision. Having the public feel that they were included fairly in the planning process is a key part of what is known as “procedural justice”. According to a survey by Xenias & Whitmarsh (2018), experts who involve the public in discussions about CCS are more likely to see its benefits and rank it higher than those who do not. Hasan et al. (2018), however, pointed out that the act of public engagement in a project that has already been decided may be better understood as a "rhetoric" activity than as a way to improve the system.

Aitken (2010) reveals that people's perceptions of procedural justice and, by extension, the fairness of the result, are boosted when they are given a greater role in making decisions and shaping plans. The study adapts this factor to model public engagement as “individuals will not be consulted”, “individuals will not be consulted except relevant NGOs”, “residents of directly affected communities will be consulted”, “residents of directly affected and surrounding communities will be consulted”, “all residents in the province will be consulted”, and “a national consultation will take place”.

Fourth, the public's acceptability of CCS plants in their communities may heavily hinge on how well officials manage and communicate information about the plants' risks assessment. It is important to stress that the confidence people have in the project's stakeholders has a direct bearing on how well information is disseminated to the local population (Ter Mors et al., 2010). Many studies have shown that people in a community are more likely to support the development of energy technology when they have access to relevant information and procedures are talked about openly (Firestone & Kirk, 2019; Musall & Kuik, 2011).

According to research by Brennan & Van Rensburg (2016), two-thirds of respondents would rather have complete transparency, even if it means accepting a reduction in pay. It was also discovered that having community representation in decision-making reduced the amount of money that needed to be paid as compensation to community members. This study takes this idea and models its effects on openness and information sharing at various stages as “public will not have access to information”, or “information available online at the approval stage” and “information available as long as the CCS plant is running”.

Fifth, remuneration is a significant component influencing local acceptability of energy technologies (Jacquet, 2012; Lienhoop, 2018; Parkins et al., 2021). Monetary incentives dispersed throughout the community, rather than just to the afflicted people, may outweigh concerns about closeness (Hoen et al., 2019; Jacquet, 2012). But nevertheless, localised monetary incentives might be seen as bribery; therefore, it is not unquestionable that compensation programmes can overcome community hostility (Aitken, 2010; Kerr et al., 2017).

Several different types of remuneration have been proposed in the literature, including cash payments to residents, payments depending on how close a home is to the affected area, and community infrastructure investments (García et al., 2016; Lienhoop, 2018). In light of these findings, the research builds a model of compensation that takes into account several measures of distributive justice ranging from "no financial benefits", to "contract preferences for local businesses in host community", and "direct financial compensation to individuals in host community".

Sixth, several of the major emitting areas and nations have been actively working to improve their CCS technology in order to lower costs and better understand their storage potential (Wennersten et al., 2015). Concerns about CCS stem from its supposedly limited storage capacity, which is seen by some as a major drawback to the technology (Oltra et al., 2010). Various aspects of CCS have been the subject of intensive engineering and feasibility research, including its capture, transit safety, and cutting-edge monitoring technologies (Bertram & Merk, 2020; Gonzalez et al., 2021; Løvseth et al., 2021; Merk et al., 2022). However, as CCS is not very familiar to the general public, information on individuals' understanding of CCS plants' storage capacities is scarce. The storage capacity of CCS can be categorised into three components: the geological storage capacity or potential of a given country, the storage capacity of individual CCS plants, and the annual injection capacity per CCS plant. In this paper, storage capacity refers to individual CCS plant storage capacity. Therefore, experts' advice was used to model the storage capacity attribute of CCS scenario plants relative to a percentage of total household emissions in a given province as "5% of total household emissions", "10% of total household emissions", and "20% of total household emissions".

Finally, the spatial complexity of climate mitigation strategies requires a cooperative approach, and various nations have distinct comparative advantages that may be used to address this problem. Various countries and regions have enacted treaties and procedures to prevent the illegal dumping of garbage on their territories. Protecting the marine environment from pollution due to the dumping of wastes at sea has been a top priority for many years, and two separate global treaties have been at the forefront of this effort: the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention) and the Protocol to the Convention, 1996 (London Protocol) (Bergesen et al., 2019). With a few exceptions, such as dredging debris, fish waste, inert, and inorganic geological material, the Protocol prohibits the disposal of all wastes or other substances. It was later proposed in 2006 by the UK, Norway, and others that the London Protocol be amended to include “CCS processes for sequestration” among the wastes that may be considered for dumping (Dixon & Birchenough, 2021).

This establishes a legal framework within the realm of international environmental law for the purpose of regulating the process of CCS. Nevertheless, it has been acknowledged that there might be a potential need for cross-border exportation in situations when a participating country lacks enough appropriate geological storage capabilities but still wants to use CCS to mitigate emissions (Bergesen et al., 2019; Dixon & Birchenough, 2021; Role et al., 2012). Countries, including those that are part of this regulatory framework, need public consent to authorise or prohibit the cross-border importation of CO_2. Despite Canada's relatively low contribution to global emissions, it has a significant share of around 15% in the current global capacity for CCS/CCUS. This provides a comparative edge for the nation in international CO_2 trade. While its economic advantages are undeniable, there may be a price to pay for accepting CO_2 since it is considered a waste product and may cause seismic activities. This idea was used to model the sources of CO_2 (cross-border import) for the proposed CCS plants as “only domestic”, “domestic and from the Netherlands”, “domestic and from the UK”, “domestic and from Norway”, “domestic and from the USA”, and “domestic and from Germany”.

The full factorial design generated from the seven attributes resulted in 8748 ($= 3^5 \times 6^2$) unique vignettes. NGene (ChoiceMetrics, 2014) was used to make a fractional factorial design, which cut down on the number of sets even more. The study chose an orthogonal design with two-way interactions because the attributes can change in different ways within and between vignettes (Auspurg & Hinz, 2015a). The fold-over method was used to produce the two-way interactions, and then a sample was systematically taken (Auspurg & Hinz, 2015b). There was a total of 72 individual vignettes used in the final design.

To control for potential learning and order effects in vignette evaluations, the study randomly (without replacement) assigned each respondent six vignettes from the pool (Auspurg & Jäckle, 2017). Each respondent was only asked to rate six vignettes (on an 11-point scale) in an effort to reduce mental weariness (see Figure 1 for an example). The vignette structure asked for ratings from -5 to +5, with the extremes being described in text as "completely unacceptable" to "completely acceptable" and "completely unfair" to "completely fair", providing a range of judgements large enough to mitigate the risks of censored responses and outliers (Kübler et al., 2018).

A ***government-industry partnership*** *has been tasked to build a carbon capture and storage (CCS) plant* ***more than 100km*** *from your home. The plant can store emissions equivalent to* ***20% of the emissions*** *generated by households in your province. It will store* ***CO_2 from domestic sources and CO_2 imported from the Netherlands****.* ***People like yourself will not be consulted but relevant NGOs will be involved*** *in the regulatory approval process.* ***At the regulatory approval stage****, the public will be informed about the CCS plant's earthquake risk assessment.* ***The CCS plant operator does not provide any financial compensation to the host community****.*

Given the assumptions stated above, **how acceptable** is this CCS development scenario to you?

-5	-4	-3	-2	-1	0	1	2	3	4	5
Completely unacceptable					neither acceptable nor unacceptable					Completely acceptable

How fair is the proposed storage of CO_2 from domestic and if applicable imported emissions to you?

Completely unfair — neither fair nor unfair — Completely fair

Figure 1: Example of a Vignette Scenario used in the Experiment

Using the concept of nudge introduced by Thaler & Sunstein (2008), respondents were asked to rate one additional vignette after being told that "survey evidence from another study in Canada indicates that 50% of the population voted in favour of the following CCS scenario". The purpose of this nudge was to examine the potential impact of the norm's effect on people, taking into consideration the reported low levels of knowledge of CCS.

3.3 Econometric Approach

Vignette data may be analysed using a variety of statistical methods. In most studies, including this one, participants react to many vignettes, and it is likely that their individual evaluations of each scenario are not independent but rather connected with one another (Auspurg & Hinz, 2015). Several approaches, such as clustered standard errors, random effects, and mixed effects regression models exist to consider such dependencies (Liebe et al., 2017). Taking into consideration the nested nature of the data (each respondent rated 12 vignettes: 6 acceptability and 6 fairness) and individual variations across participants, random effects regression models were employed for this analysis (Atzmüller & Steiner, 2010). Employing a simple least squares regression and neglecting the fact that respondents rate many vignettes would result in biased standard errors of the model coefficients (Bosker, 2012).

All participants read a short script at the start of the experiment (based on the stated preference literature). The script (Appendix: Questionnaire Section 2) educated responders about the hypothetical nature of the vignette scenarios and created a baseline of comprehension. Consequently, the study presumes that the respondents' interpretations of the fairness and acceptance responses were consistent. Therefore, there was no need to account for differences in response scales, also known as "differential item functioning," or DIF, during the model estimation phase (Greene et al., 2021), as it was assumed that all respondents would rate a given CCS plant scenario as "completely acceptable" or "completely fair" if it fully satisfied their preferences.

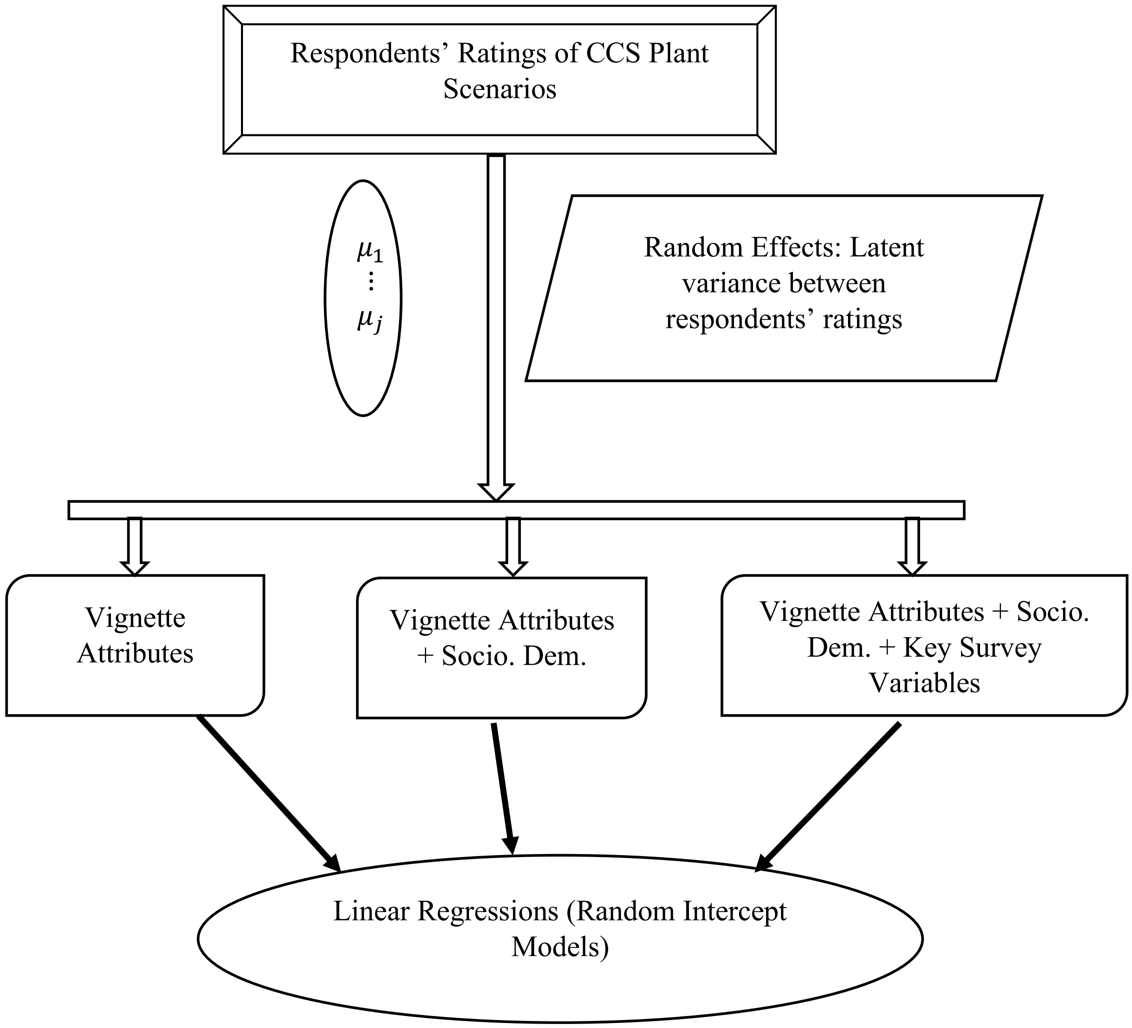


Figure 2: Flowchart of Random Effects Model Analysis

The linear random intercept model is specified as:

$$y_{ij} = \beta' x_{ij} + \mu_j + e_{ij} \tag{1}$$

Where y_{ij} is the rating variable for the ith respondent of the jth vignette scenario, x_{ij} is a vector of CCS project attributes, e_{ij} are respondent level errors, and μ_j are vignette level errors or random effects. The vector β collect the coefficients of the attributes, also called fixed effects.

The respondent level and vignette errors are assumed independent, with respondent level errors following a normal distribution with variance $\sigma_{e.}^{2}$ The distribution of the random effects μ_j is assumed to be:

$$\mu_j \overset{iid}{\sim} N(0, \sigma_u^2) \quad (2)$$

Where σ_u^2 is the vignette level variance. In other words, a normal distribution is assumed for the random effects, which is consistent with the common assumption that they are independent and identically distributed (therefore homoscedastic) across vignette levels.

Another assumption is made, which is not often stated explicitly: that the random effects on the covariates are independent on average. This is known as the exogeneity of the covariates, and it is stated as follows:

$$E(\mu_j | x_{1j}, x_{2j}, \dots, x_{nj}, z_i, v_i) = 0 \quad (3)$$

Exogeneity ensures the unbiasedness of the estimates (Ebbes et al., 2004; Grilli & Rampichini, 2011, 2015; Kim & Frees, 2007).

The base model (model with only attributes – equation 1) was extended to include respondents' socio-demographic variables.

$$y_{ij} = \beta' x_{ij} + \gamma' z_i + \mu_j + e_{ij} \quad (4)$$

Where z_i is a vector of respondents' socio-demographic variables. The vector γ collect the coefficients of the respondents' socio-demographic variables. Finally, equation 4 was then extended to include other key survey variables.

$$y_{ij} = \beta' x_{ij} + \gamma' z_i + \delta' v_i + \mu_j + e_{ij} \quad (5)$$

Where v_i is a vector of other survey variables and the vector δ collect the coefficients of those survey variables.

$$x = \begin{bmatrix} proximity \\ implementation \\ risk\ info \\ consultation \\ benefits \\ storage\ capacity \\ cross-border\ import \end{bmatrix}; z = \begin{bmatrix} age \\ gender \\ household\ income \\ education \\ household\ size \end{bmatrix}; and\ v = \begin{bmatrix} CCS\ knowledge \\ CCS\ benefits \\ CCS\ risks \\ environmental\ risks \\ institutional\ trust \\ CCS\ support \\ induce\ seismisity \end{bmatrix}$$

Stata 17.0 was used to estimate the random intercept models based on the idea that participants' acceptance or fairness benchmarks would change between vignettes with different levels of attributes (Auspurg & Hinz, 2015a). The likelihood ratio test demonstrates that this model specification performs better in the analysis when compared to an ordinary least squares regression model.

4.0 Results

4.1 Sample and Descriptive Data Analysis

Table 2 below presents the summary statistics of the respondents' characteristics. From to the results, most respondents (67.97%) are in their prime working lives (between the ages of 19 and 59). In this sample, about 17.76% are young adults (ages 19–29), 33.14% are adults (ages 30-49), 17.07% are late adults (ages 50–59), and 32.04% are seniors (ages 60 and more). This estimate is quite similar to the official data from Statistics Canada, which puts the median age at 41 years old (Statistics Canada, 2021b).

Table 2: Summary Statistics of Respondents' Socio-demographics and Survey Variables

Variable	**Description**	**Sample (n = 1,002) (Percentages)**	**Census Benchmark (2021)**
Age (years)	19 – 29	17.76	19.99
	30 – 39	17.17	14.46
	40 – 49	15.97	12.81
	50 – 59	17.07	13.43
	60 +	32.04	25.33
Gender	Male	47.50	49.30
	Female	51.40	50.70
	Other	0.80	-
	Prefer not to say	0.30	-
Level of Education	College	26.35	21.80
	Graduate	10.98	8.40
	High School	30.04	26.70
	Technical or trade	10.28	8.70
	certificate	21.16	17.50
	Undergraduate	1.20	-
	Prefer not to say		
Willingness to take Risks	Completely unwilling	8.48	-
	Unwilling	23.35	-
	Neutral	31.54	-
	Willing	29.14	-
	Very willing	7.19	-
	Prefer not to say	0.30	-
Place of Residence	Rural	13.27	17.80
	Urban	86.73	82.20
Political Orientation	Green	47.01	-
	Left	22.85	-
	Right	29.44	-
	Centrist	0.70	-

	No. of obs	***Mean***	***Median***	***Min***	***Max***	***SD***
Income	921	129,061.80	54,000	2,000	50,000,000	1,648,342
Household size	1,000	2.50	2	1	14	1.48

In terms of gender, the results show that males represented 47.5%, females 51.0%, and non-binary, transgender, and non-identified people 1.10%. Since women constitute 50.7% of the Canadian population over the age of 20 (Statistics Canada, 2021b), and around 51.40% of those who completed the survey fall into this demographic, it appears that this sample accurately represents the country as a whole. Considering the stereotype that only men are interested in the energy sector, it's encouraging to see that women make up more than half of the respondents.

Participants' levels of education varied greatly, from advanced degrees to certificates in technical fields. The results (Table 2) indicate that 26.35% of the respondents are college graduates, 10.28% completed trade or technical school, 21.16% hold an undergraduate degree, 10.98% hold a graduate degree, and 1.2% did not specify their level of education. When compared to the average of Canada, where only around 65% of the workforce has some kind of post-secondary education, this is an above-average figure (Statistics Canada, 2019). The fact that it was conducted online and included non-working adults (such as retirees) makes this inevitable.

Different people will react differently to the same risk because optimists will concentrate on the prospective benefits and pessimists will dwell on the potential drawbacks of any given option (Dohmen et al., 2018). Frey et al. (2021) argue that self-reported propensity measures are more likely to capture individual variations in risk preferences linked to sociodemographic characteristics like sex and age, hence, this is what was done. Respondents were asked about their willingness to take risks. The results (Table 2) show that 8.48% of the respondents were completely unwilling to take risks, 23.35% were unwilling to take risks, 29.14% were willing to take risks, 7.19% were very willing to take risks, and 31.54% were risk neutral. This implies that more than a third of the respondents (36.33%) are risk lovers, about a third are risk averse (31.83%), and about a third are risk neutral (31.54%). The sample was also representative of both rural and urban inhabitants. More than three-quarters (86.73%) of the survey respondents said they were in metropolitan cities, while 13.27% said they were in a rural place. Using Stephanie & Graham

(1989) study as a guide, respondents were presented with a triangle to indicate which vertex best describes their political orientation (with the vertices corresponding to left, right, and green). The results in Table 2 above show that the majority of the respondents (47.01%) were green-oriented, 22.85% are left-wing, 29.44% were right-wing, and 0.70% were centrists (they did not lean toward any of the political orientations).

The income variable was measured as both continuous and categorical, and the majority of the respondents provided their approximated income figures. The few respondents who provided the income interval were then extrapolated to get an approximate figure. The data shows that the incomes of the respondents are distributed quite unevenly. Incomes range from $2,000 to $50,000,000, with a median of $54,000 and a mean of $129,062. According to a Statistics Canada (2022) report from 2020, the median after-tax income for Canadian families and single people was $66,800. Our sample may not be statistically representative of the Canadian public at large (a potential selection bias), but it does give insight into a subset of the population that may contribute a wide variety of viewpoints to the question of whether or not the public would approve a CCS project. The household sizes of the respondents likewise ranged widely, from one to fourteen members, with a mean of 2.5 and a median of 2. The typical Canadian household, according to Statistics Canada (2021), has 3.2 people. This reveals some dynamics in the socio-demographics of the respondents.

4.2 Summary Statistics of Selected Survey Variables

Respondents' objective knowledge about CCS-induced seismicity was assessed. The results (Table 3) show that about two-third of the respondents (65.97%) responded true to the question, "CCS will always cause earthquakes, which will always be felt by humans on the surface of the earth". According to the science, it is extremely unlikely for an earthquake of this magnitude to be caused by CCS activities. Consequently, an affirmation of the veracity of this assertion indicates a deficiency in one's comprehension of the technology. This suggests that a significant portion of the population lacks familiarity with the scientific principles underlying the technology. Respondents were also asked to indicate their general level of support for the CCS technology. The results in Table 3 below show that a significant number of the respondents either support (31.30%) or strongly support (11.57) the technology. While about 12.50% oppose or strongly oppose (9.71%) the technology. 34.92%, however, neither support nor oppose the technology.

Respondents' subjective knowledge about CCS was assessed in the survey. The summary statistics in Table 3 below show that about 22.85% of respondents said they never heard about CCS while about 24.55% of the respondents reported to have heard about it. About 35.43% know just a little and about 12.57% know a fair amount. However, only about 4.59% reported to know a lot about the CCS technology. Despite its existence for decades, the literature has consistently reported low levels of knowledge and awareness about the technology (Ashworth et al., 2019; Lima et al., 2021; Wang et al., 2019). Although some studies have reported relatively high levels of CCS knowledge in Canada (Boyd et al., 2017; Zhang et al., 2022), the lack of proper understanding of the technology has led to questions about the validity of using only surveys to assess public support for the technology.

Table 3: Summary Statistics of Survey Variables

Variable	Description	Sample (n = 1,002) (Percentages)
CCS Induces Seismicity	True	65.97
	False	34.03
CCS General Support	Strongly oppose	9.71
	Somewhat oppose	12.50
	Neither support nor oppose	34.92
	Somewhat support	31.30
	Strongly support	11.57
CCS Knowledge	Never heard about it	22.85
	Heard about it	24.55
	Know just a little	35.43
	Know a fair amount	12.57
	Know a great deal	4.59
Climate change risks	None existing	6.19
	Low	15.97
	Moderate	34.93
	High	41.82
	Prefer not to say	1.10
Trust in fed gov't energy regulator	Not at all	24.45
	A little	51.20
	A lot	17.76
	Prefer not to say	6.59
CCS will increase economic growth	Not at all	13.57
	Somewhat	36.23
	Very little	31.24
	Very much	10.78
	Prefer not to say	8.18
CCS will lower the drive to cut CO_2 emissions	Not at all	10.38
	Somewhat	40.82
	Very little	27.15
	Very much	14.47
	Prefer not to say	7.19

The survey also included an assessment of people's perceptions of the risks associated with climate change. The results indicate that a significant proportion (41.83%) of the participants hold the belief that the risks associated with climate change are of a very high magnitude, while around 34.93% of the respondents perceive these risks to be of a moderate level. However, around 15.97% of individuals hold the belief that risks associated with climate change are minimal, and approximately 6.19% maintain the opinion that climate change risks do not exist. The acceptability and support for various mitigation techniques are significantly influenced by individuals' beliefs on the risks associated with climate change (Evensen et al., 2023; Kácha et al., 2022; Spence et al., 2010). Acceptance of CCS, however, may be driven by more prominent motivations, given the numerous facets of CCS, including economic development, distributive fairness and justice, induced seismicity, and climate mitigation.

The survey also assessed respondents' perceptions about CCS impact on economic growth and the need to reduce emissions. The summary statistics in Table 3 show that about 10.78% of the respondents believe that CCS will increase economic growth very much, while about 31.24% believe it will increase economic growth just a little. 36.23% believe it will increase economic growth somewhat, while about 13.57% believe it will not increase economic growth at all. Regarding the need to transition to lower carbon economies, about 14.47% believe it will very much lower the drive to cut down on emissions, while about 27.17% believe that the risk of lowering the drive to cut down on emissions is very little. The majority (40.82%), however, believe it will somewhat lower the drive to cut down on emissions, while only about 10.38% believe it will not lower the drive to reduce emissions. There are several opinions on the importance of the CCS technology. Some contend that CCS only serves as a lifeline for the oil and gas sector to sustain its operations (Gonzalez et al., 2021), while others advocate for its substantial contribution to climate change mitigation (Longa et al., 2020).

The survey also explored individuals trust in institutions, particularly federal government energy-regulating institutions. Table 3 above shows that about 17.76% of the respondents have a lot of trust in federal government energy regulators, while the majority (51.20%) have just a little trust in government energy regulators. However, about one quarter (24.45%) of the respondents do not have any trust in federal government energy regulators. The level of trust placed in government energy organisations is indicative of the degree of confidence individuals have in their ability to effectively manage energy-related matters (Stretesky et al., 2023; Truong et al., 2019; Yang et al., 2016). The delegation of monitoring and regulating responsibilities for a complex energy technology like CCS may be limited to organisations that have a high level of public confidence.

4.2 Summary of Vignette Ratings

Table 4 below shows the summary statistics of the different vignette ratings presented by respondents. Regarding CCS project vignette ratings, respondents provided both acceptance and fairness ratings to the vignette scenarios presented to them. Figure 3 below shows a bell-shaped rating distribution (excluding the two extremes), with a mean acceptance rating of -0.33 and a standard deviation of 2.93 (Table 4). The figure depicts that about 13.29% of the respondents view the proposed CCS plants as completely unacceptable, 14.95% view them as neither acceptable nor unacceptable, and about 4.66% view them as completely acceptable.

Table 4: Summary of Vignette Ratings

Variable	***No. of obs***	***Mean***	***Median***	***Min***	***Max***	***SD***
Vignette (acceptance)	6,012	-0.333	0	-5	5	2.93
Vignette (fairness)	6,012	-0.369	0	-5	5	2.88

It is also interesting to note that after excluding the middle ratings, there appears to be a balance between the opposers and supporters of the proposed CCS plants (43.45% opposers and 41.61% supporters). This indicates that unique CCS plant features have the potential to tip the neutral ratings to either side of the balanced scale. This observation is consistent with that of Whitmarsh et al.'s (2019) cross-national survey, which also shows a relatively lower level of support for CCS in Canada when compared to the United States, the United Kingdom, and Norway.

However, according to Wang et al. (2021) findings, participants in a randomised control experiment conducted among undergraduate students in China exhibited a noteworthy level of support for CCS that was much higher than the average level. This increase in support was shown after the participants were exposed to social norm information. This suggests that respondents' values and norms influenced their assessments of CCS plant scenarios.

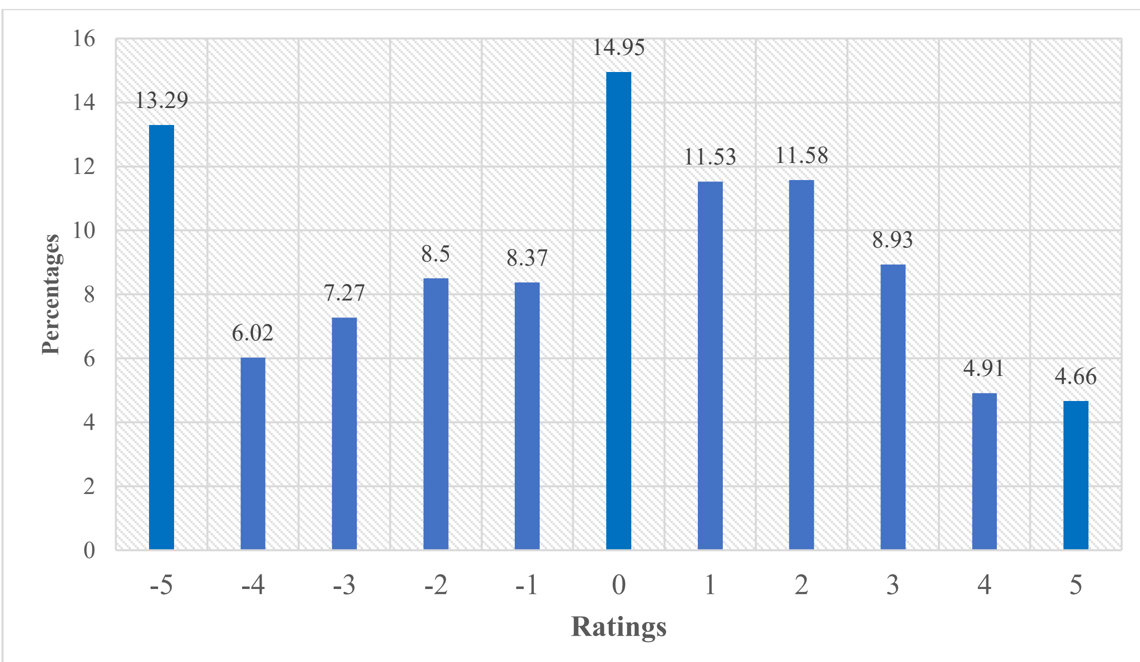


Figure 3: Acceptance vignette ratings

A similar pattern of ratings is observed with the fairness vignette questions. From Table 4 above, the average fairness rating for the proposed CCS plants is -0.359 with a standard deviation of 2.88. Figure 4 below shows that about 13.32% of the respondents rated the vignette scenarios as completely unfair, 16.82% rated them as neither fair nor unfair, and 3.84% rated them as completely fair. Also, as observed with the acceptance ratings, excluding the neutral ratings, about 42.87% of the respondents view the proposed CCS plants as unfair, while about 40.32% view them as fair. Again, this demonstrates that unique CCS plant variables can shift the fairness perception of about 16.82% of the respondents to either side of the camps.

Little research has been done on the importance of fairness (distributive and procedural) in the context of CCS (Seigo et al., 2014). There are a few articles that directly discuss the importance of fairness, and other research that touch on the issue indirectly (Seigo et al., 2014; Terwel et al., 2009, 2011). The perception of fairness in procedures has been shown to positively correlate with increased levels of trust and eventually more acceptance. Many things contribute to people's level of trust in an organisation, including their confidence in its ability to carry out the CCS project, the clarity and openness of its communications, its regard for the public interest, the consistency of its decision-making processes, and the technological success of CCS (Terwel et al., 2009; Upham & Roberts, 2011; Yang et al., 2016).

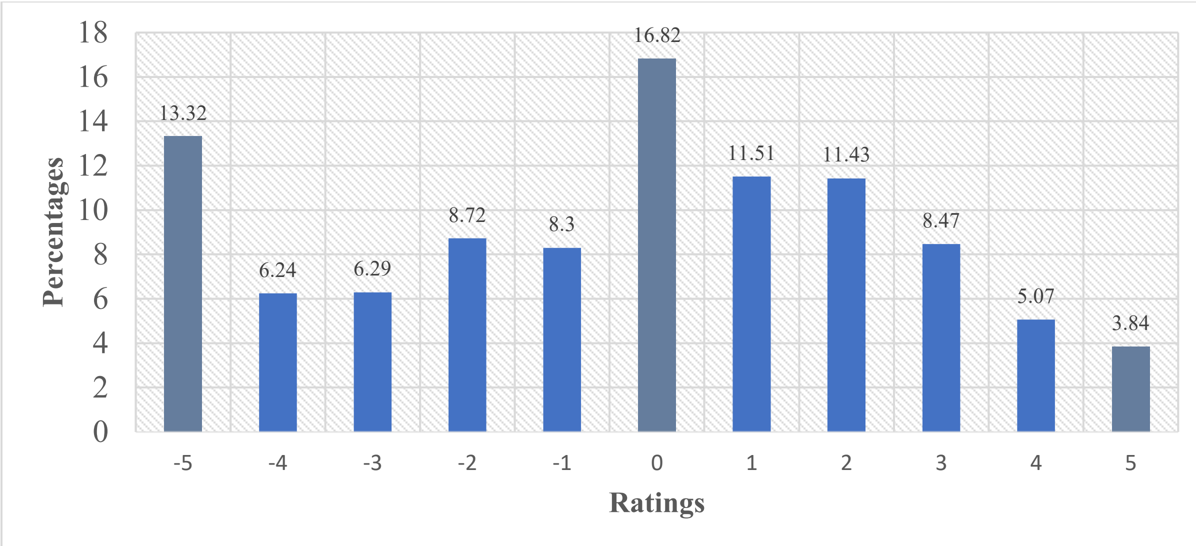


Figure 4: Fairness Vignette Ratings

4.3 Governance and Monitoring of CCS Projects

Shale gas reservoirs are proposed to be the storage wells for captured CO_2, and induced seismicity monitoring is an essential component of those reservoirs as well as managing and mitigating the latent risks related to induce earthquakes. CCS plants may be particularly susceptible to monitoring on a regional and global scale because of the distinct signature of climate change and the localised nature of CCS plant risks (Keeling et al., 2011). The science of the CCS technology guarantees its safety. However, Lackner & Brennan (2009) noted that the public is generally worried about technical solutions that lead to situations that might spin out of control (as can be seen in the discussions around the use and development of artificial intelligence). The social licencing of CCS might be improved by exposing its monitoring and administration to public scrutiny and by entrusting several organisations with the building of a decision tree capable of handling improbable situations.

Respondents were asked about who should be responsible for the evaluation of site-specific conditions of CCS projects (Figure 5). 23.05% of the respondents indicated that the federal government should be entrusted with that responsibility; 18.46% indicated that an independent body should be set up to handle that; 17.27% indicated it should be handled by CCS operators; and 16.47% indicated that it should be the responsibility of an environmental organisation. Next to those institutions are the provincial government (8.88%), research institutions and universities (8.48%), taxpayers (5.79%), and specialised politicians (1.6%).

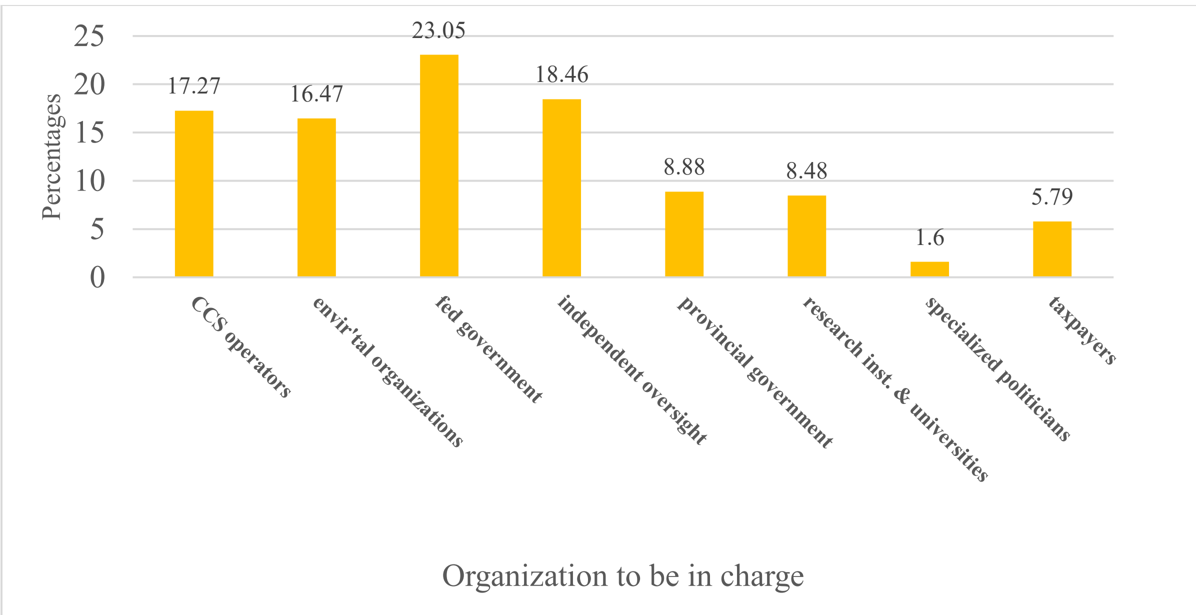


Figure 5: Organisation that should be responsible for evaluating CCS site-specific conditions

(In your opinion, which organisation should be responsible for the evaluation of site-specific underground conditions for storing CO_2 long term?)

A significant site-specific factor that raises concern among stakeholders is the potential for CO_2 leakage from CCS facilities (Tcvetkov et al., 2019). The leakage of CO_2 can result in significant ramifications for the surrounding ecosystems, including acidification and pollution caused by the mobilisation of heavy metals (Elzahabi & Yong, 2001). It is anticipated that the oversight of such a significant matter will be delegated to institutions possessing a high degree of proficiency in the field and deemed trustworthy by the general populace.

The participants were asked in a targeted manner regarding the entities that ought to assume the responsibility of monitoring the potential leakage of CO_2 (Figure 6). The majority of the respondents (27.15%) indicated that CCS project operators should monitor potential CO_2 leakages. The federal government (18.16%), independent organisations (16.97%), and environmental agencies (16.57%) were the other top four institutions respondents indicated should handle the monitoring of CO_2 leakages. Provincial governments (9.28%), research institutions/universities (5.89%), taxpayers (3.89%), and specialised politicians (2.1%) were the least preferred institutions for the monitoring of CO_2 leakages.

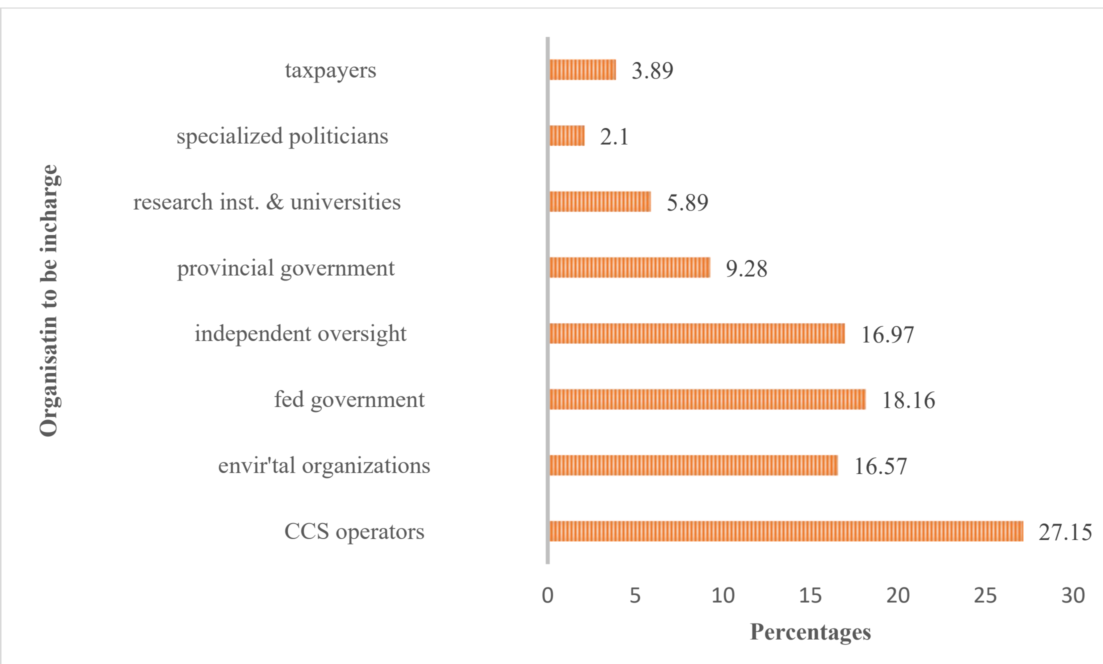


Figure 6: Organisation that should be responsible for monitoring CO_2 leakage during operations

(In your opinion, which organisation should be responsible for monitoring CO_2 leakage during operations?)

A key site-specific concern about CCS wells is the possibility of induced seismicity. Even though the chances of CCS-induced seismicity are slim in many regions, the dissemination of information pertaining to seismic monitoring endeavours has been observed to elicit heightened concerns regarding potential hazards (Seigo et al., 2011). In fact, it is the primary determinant of support or resistance towards subsurface energy technologies, making it the most crucial risk factor (Evensen et al., 2022; Haemmerli & Stauffacher, 2020; Lokuge et al., 2023). Nevertheless, the topic of induced seismicity has not received much attention in recent conversations around CCS. Given the significance of this matter, it is very likely that individuals would delegate the task of monitoring to institutions that they not only have faith in but also possess a strong belief in their competence.

Participants were asked about which institutions should be responsible for monitoring CCS-induced seismic risks (Figure 7). The results show that the majority of the respondents (21.46%) noted that the CCS operators should be in charge of monitoring seismic risks. The federal government (20.16%), independent (17.56%), and environmental organizations (16.77%) were the other top four institutions that respondents indicated should be responsible for monitoring induced seismic activities. These findings suggest that a combined effort has a better chance of influencing public opinion. Similar results from a study performed by Boroumand, (2015) revealed that respondents favoured a team-based strategy for seismicity education.

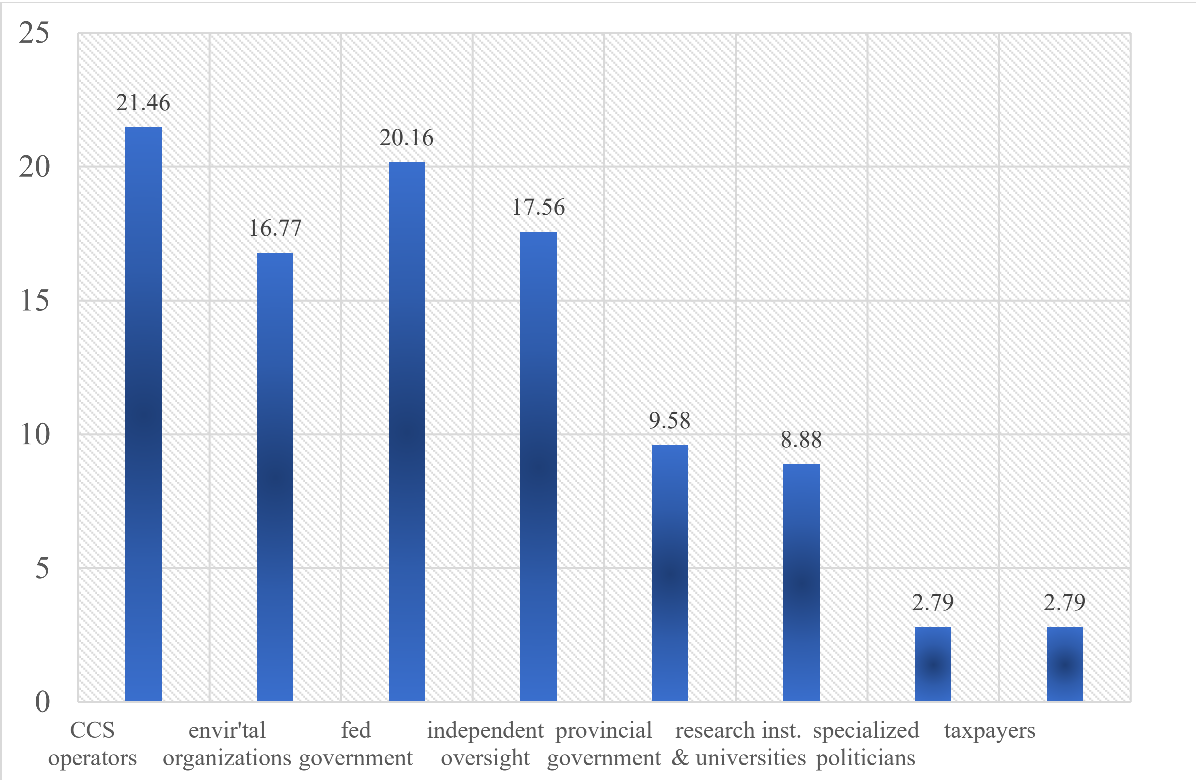


Figure 7: Organisation that should be responsible for monitoring CCS seismic risks

(In your opinion, which organisation should be responsible for monitoring CCS seismic risks during operations?)

Finally, when respondents were asked about the minimum acceptable level of monitoring to allow for the operation of a CCS plant (Figure 8), 40.92% indicated that it should be able to detect and mitigate earthquake risks. 21.96% indicated that monitoring should be able to assess the likelihood and severity of earthquakes. 20.46% indicated that monitoring to observe seismic risks will be sufficient, while only about 16.67% indicated that the monitoring should be able to forecast the likelihood of earthquakes.

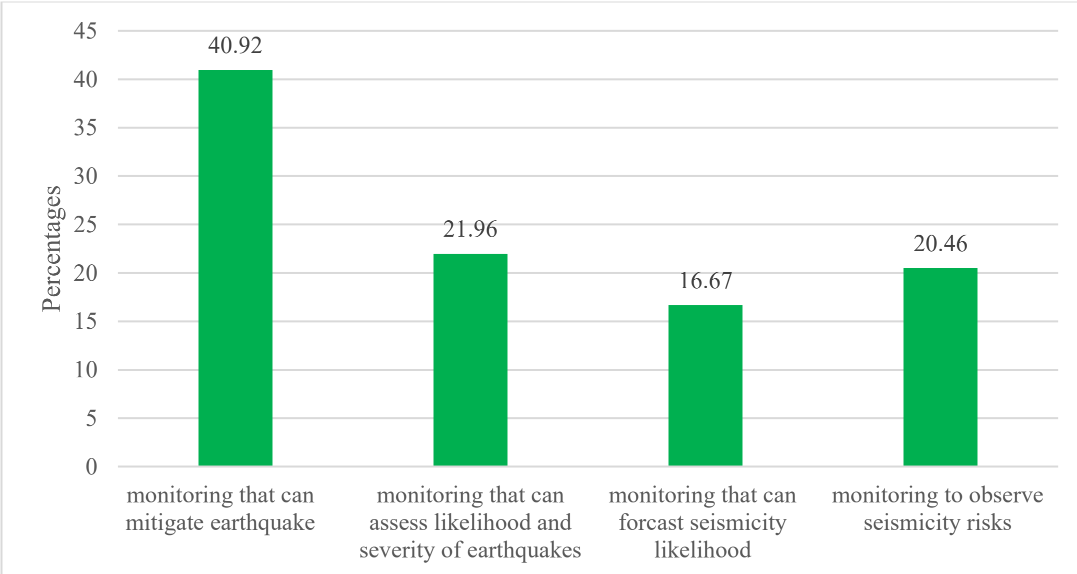


Figure 8: Minimum acceptable level of monitoring of CCS projects

(In your opinion, what should be the minimum acceptable level of monitoring of CO_2 storage facilities to assure their safe operations?)

4.4 Results of Random Effect Models

Table 5 presents the results of the random effects regression models, i.e., random intercept models, separately for acceptance and fairness. Models 1 and 2 include only vignette attributes as independent variables and acceptance and fairness ratings as dependent variables, respectively. Models 3 and 4 add respondents' characteristics and principal components of heterogeneity survey variables to the model 1. The Breusch and Pagan Lagrangian multiplier test for random effects show that the random intercept model specification is preferred over an ordinary least squares regression model (*prob > chibar2 = 0.0000*). The intra-class correlations for the two base models (acceptance and fairness) are 0.6334 and 0.6499 in models 1 and 2, respectively, and indicate a moderately high correlation of the six responses per respondent.

Further, to test whether respondent ratings were independent of the vignette attributes included in the vignette scenarios, respondents who rated all six scenarios as completely unacceptable (-5) or completely acceptable (+5) regardless of the attribute levels were excluded from models 5 and 6 (Appendix: Table 13). Comparing the results of these two models without the extreme ratings to the base models, we do not find any significant differences. This suggests that the estimates are robust and that the vignette attributes and their levels influence respondents' ratings. The coefficient estimates for each attribute are presented relative to the benchmark level of that attribute (called status quo in CE literature) in the context of CCS development in Canada.

Cross-border import of CO_2 for storage across models has the strongest effect on CCS plant scenario acceptance. Measured against storing only domestically emitted CO_2, the least preferred scenario involves importing CO_2 from Germany (-0.739) to be stored in CCS plants in Canada. When specifically asked about how fair that is, the rating increased towards being completely unfair *(-0.789*). This negative effect on acceptance (and *fairness*) from the cross-border importation of CO_2 is not only in relation to Germany but also to other countries such as the Netherlands (-0.728) *(-0.693*), the UK (-0.674) *(-0.723*), the US (-0.588) *(-0.568*), and Norway (-0.580) (*-0.633*).

Table 5: Results of Random Effects Regression Models for Vignette Attributes, Socio-demographics, and Principal Components of Heterogeneity Variables.

Variables	Model 1 Acceptance	Model 2 Fairness	Model 1 + Socio-dem.	Model 1 + Full model
Implementation				
gov't-industry partnership	0.119*	0.100*	0.132**	0.160**
	(0.062)	(0.061)	(0.066)	(0.074)
fed gov't	0.103*	-0.035	0.105	0.100
	(0.061)	(0.059)	(0.065)	(0.072)
Proximity				
between 50 km and 100 km	0.136**	0.181***	0.175***	0.171**
	(0.060)	(0.056)	(0.062)	(0.071)
more than 100 km	0.241***	0.282***	0.265***	0.250***
	(0.062)	(0.059)	(0.065)	(0.071)
Capacity				
10% of hh emissions	-0.024	0.003	-0.031	-0.005
	(0.060)	(0.059)	(0.064)	(0.073)
20% of hh emissions	0.014	0.095	0.040	0.110
	(0.061)	(0.061)	(0.064)	(0.073)
Cross-border import of CO_2				
domestic and the Netherlands	-0.728***	-0.693***	-0.718***	-0.701***
	(0.096)	(0.091)	(0.101)	(0.111)
domestic and the UK	-0.674***	-0.723***	-0.685***	-0.684***
	(0.093)	(0.092)	(0.100)	(0.110)
domestic and Norway	-0.580***	-0.633***	-0.588***	-0.588***
	(0.086)	(0.085)	(0.092)	(0.100)
domestic and the US	-0.588***	-0.657***	-0.581***	-0.634***
	(0.096)	(0.090)	(0.100)	(0.107)
domestic and Germany	-0.739***	-0.789***	-0.773***	-0.762***
	(0.0959)	(0.091)	(0.102)	(0.104)
Consultation				
only relevant NGOs	0.101	0.018	0.107	0.103
	(0.085)	(0.082)	(0.090)	(0.100)
only residents of directly affected communities	0.280***	0.181**	0.306***	0.364***
	(0.083)	(0.083)	(0.088)	(0.100)
residents of surrounding communities	0.239***	0.135	0.262**	0.247**
	(0.083)	(0.105)	(0.088)	(0.100)
all residents in the province	0.354***	0.250***	0.391***	0.379***
	(0.086)	(0.089)	(0.090)	(0.100)
a national consultation	0.327***	0.188**	0.346***	0.386***
	(0.082)	(0.089)	(0.086)	(0.100)
Information				
only at regulatory approval stage	0.519***	0.444***	0.553***	0.571***
	(0.062)	(0.061)	(0.066)	(0.072)
throughout the plant's lifespan	0.567***	0.467***	0.582***	0.577***
	(0.0633)	(0.064)	(0.068)	(0.075)
Benefits				
contract preference for local businesses	0.421***	0.307***	0.443***	0.473***
	(0.060)	(0.062)	(0.063)	(0.071)

direct financial compensation to individuals affected	0.627*** (0.066)	0.577*** (0.064)	0.655*** (0.070)	0.645*** (0.077)

Continuation of Table 5

Variables	Acceptance	Fairness	Socio-dem.	Full model
Gender			0.735***	0.451***
			(0.155)	(0.149)
Age			-0.330***	-0.197***
			(0.051)	(0.050)
Log household income			0.131	0.012
			(0.095)	(0.084)
Education			0.004	-0.016
			(0.063)	(0.060)
Household size			0.002***	0.002***
			(0.000)	(0.000)
CCS knowledge				0.296***
				(0.070)
Perception of CCS benefits				0.019
				(0.069)
Perception of environmental risks				-0.163***
				(0.052)
Trust in federal gov't energy regulator				-0.420***
				(0.111)
Perception of CCS risks				-0.285***
				(0.067)
CCS general support				0.894***
				(0.091)
CCS induced seismicity				0.413***
				(0.161)
Constant	-0.896***	-0.735***	-1.340	-2.633**
	(0.131)	(0.135)	(1.059)	(1.038)
Number of vignettes ratings	6,012	6,012	5,430	4,218
Number of respondents	1002	1002	904	703
Std. dev. random effect (*sigma_u*)	2.2926	2.3068	2.2208	1.7807
Std. dev. error (*sigma_e*)	1.7442	1.6931	1.7521	1.7351
Intra-class correlation (*rho*)	0.6334	0.6499	0.6164	0.5130
Wald chi^2	283.75	257.73	1468.68	2570.03

*Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

Notice that for the US, even though the effect is still negative, the magnitude in terms of both fairness and acceptance is lower. Considering the global impacts of climate change and the localised risks of CCS plants, this result reveals a lower preference for CO_2 trading between countries. This is because CO_2 may be regarded as sewage (and it is) (Lackner & Jospe, 2017), and countries might not want to be on the receiving end. Despite the 2009 amendment to Article 6 of the London Protocol in the EU, which permits countries to consent to the export and import of CO_2 for offshore geological storage, thereby eliminating a major international legal obstacle to CCS and enabling the transportation of CO_2 across national boundaries for offshore storage (Bergesen et al., 2019; Dixon et al., 2015; Dixon & Birchenough, 2021; Role et al., 2012), our results show that there exists a prevalent negative public perception towards cross-border importation of CO_2. This finding also relates to the literature on the transnational transportation of waste (Kellenberg, 2015; Liddick, 2010; Pellow, 2007). This suggests that if the correct disposal costs, environmental rules, compensation, monitoring, and compliance framework are in place, people can be persuaded to support the international trading of CO_2.

CCS plant acceptability is also significantly impacted by compensation. Against no financial compensation at all, the most preferred attribute scenario involves financial compensation (0.627) to individuals directly affected by the siting and operation of the CCS plant. This effect is stronger than the option for contract preference for local businesses and services (0.421). When asked about how fair those compensation schemes are compared to no compensation, there is still a positive effect on fairness for individual compensation (0.577) and preference for local services (0.307). Prioritising local firms and services in contracts and providing compensation directly to impacted persons over no financial compensation at all represent a desire for fairness in a proximity-based compensation system revealed by earlier research (Mills et al., 2019; Parkins et al., 2021; Walker & Baxter, 2017). This suggests that people might be willing to tolerate some degree of risk associated with CCS plants in exchange for their fair share of the pie.

How effectively and transparently authorities manage and distribute information regarding the risk assessment of CCS facilities is also crucial to the plants' acceptance. Relative to not sharing information about the risk assessment of the CCS plant, public acceptance hinges not only on making information available online throughout the plant’s lifespan (0.567), but also on making the information available at the regulatory approval stage (0.519). Regarding how fair that is against not sharing the risk assessment information with the public, the fairness rating increases when the risk assessment information about the CCS plant scenario is made available at the regulatory approval stage (0.444) and updated information is available online as long as the plant is running (0.467). This positive relationship between acceptance and access to information was also observed by Firestone & Kirk (2019) and Musall & Kuik (2011). Some individuals might even be willing to accept lower compensation in return for access to information (Brennan & Van Rensburg, 2016). This implies that prioritising communication, information sharing, and transparency in the design of CCS plants is essential to enhancing their public acceptance.

Likewise, the concept of procedural justice has been observed to have a significant and robust impact on acceptance. Relative to no consultation at all, conducting a national consultation (0.327) as an integral part of the planning process for a CCS plant's construction increases its public acceptance. Similarly, consulting the residents of the host province (0.354), residents of the directly affected communities (0.280), or residents of the directly affected and surrounding communities (0.239) has a positive effect on the acceptance of proposed CCS plant scenarios. However, consulting relevant NGOs about proposed CCS plants, relative to the option of no consultation at all, has no statistically significant impact on public acceptance of CCS plants. When asked about how fair those levels of consultation are in light of procedural justice, relative to no consultation, national consultation (0.188), provincial consultation (0.250), and consulting residents of the directly affected communities (0.181) positively influence the perception of fairness. This result is in line with the findings of Aitken (2010), Liebe & Dobers (2019), and Xenias & Whitmarsh (2018). This suggests that involving the public in the decision-making process has the capacity to enhance the level of acceptance of CCS facilities.

Another significant and robust determinant of public acceptance of CCS scenario plants is proximity. Against the option of having a CCS plant located less than 50 km from the place of residence, respondents not only prefer a distance of between 50 km and 100 km (0.136) but also have a greater preference for a farther distance of more than 100 km (0.241). When specifically asked about how fair those levels of proximities are relative to the option of less than 50 km, we observe a much higher perception of fairness for a proximity of more than 100 km (0.282), as well as between 50 km and 100 km. This finding is in line with the NIMBY description given by Krause et al. (2014) and dismisses the assertion of Boyd et al. (2017) that living close to such facilities is positively associated with acceptance. However, as noted by Wolsink (2006), labelling this as NIMBY behaviour may obscure our understanding of the real motives, as this relates more to the issue of fairness and justice in the site selection. Therefore, in modelling a potential CCS plant scenario, it may be essential to look at proximity with the lens of fairness instead of the label of NIMBY.

Furthermore, the effect of the system of administration and how the CCS plant is put into use on public opinion is revealing. Relative to the option of a CCS plant scenario being implemented by an industry consortium, government-industry partnership (0.119) or only by the federal government (0.103) is preferred. In addition, just as we have a government-industry CCS development council in Alberta (IEA, 2008), fairness-related ratings reveal that government-industry partnerships (0.100) are regarded as being fair as compared to industry consortia. This makes sense because many energy technologies are often regarded as only for-profit ventures (Strielkowski et al., 2020), and as such, a government partnership may be reassuring that public interest will be prioritised. As per our prior analysis, it is noticeable that the federal government is deemed more suitable for assuming responsibility for specific types of CCS projects monitoring.

After controlling for economic, transparency, and fairness-related factors, it has been observed that the impact of storage capacity on the acceptance of CCS plant scenarios is relatively low and statistically insignificant. This indicates that deliberations regarding CCS are focused more on the social (fairness and justice) and economic (compensation) elements of the technology than on its place in the battle against climate change. This implies that communication efforts to improve public understanding and acceptance should focus on the socio-economic aspects of the technology instead of its technicalities and climate mitigation capacity.

Effects of Respondent Socio-demographics on CCS Acceptance

Public opinion and perceptions matter tremendously in how people see issues and technologies like CCS, according to the research on CCS and related energy technologies (Howell et al., 2019; Moon et al., 2020; Pianta et al., 2021), which suggests that respondent characteristics may possibly alter their judgement of CCS plant scenarios. As such, Model 3 incorporates a set of covariates pertaining to sociodemographic factors that have been highlighted in the literature as having effects on individuals' perceptions of energy technologies. The findings confirm the relevance of respondent socio-demographic characteristics as drivers of public acceptability of CCS based on these control variables in Model 3. Table 5 findings indicate that male gender significantly influences the acceptance levels of CCS plants, as reflected in vignette scenario ratings that are 0.735 scale points higher. The observed positive coefficient among males could potentially signify the prevalence of male-oriented focus in the energy sector, a matter of significant prominence in the western part of Canada. These findings align with the observations made by Yang et al. (2016), which indicate that males exhibit a higher likelihood of accepting CCS compared to women. Nevertheless, according to Arning et al. (2019) study, no statistically significant difference was noted in the acceptability levels of CCS between men and women. This contradictory finding might perhaps be attributed to the varying degrees of participation of men and women within the public debate on energy issues across different countries. It is also important to acknowledge that there is a higher likelihood for males to recognise emerging technologies and engage in public discourse around them, as shown by several studies (Miller et al., 2007).

It's evident that various individuals of different ages think differently, and that different strategies are needed to persuade them (Stephens et al., 2009). The relevance of age in predicting the acceptance of CCS plants among respondents is noteworthy. The findings indicate that there is a statistically significant negative correlation between age and acceptance, with a decrease of 0.330 scale points per decade of age increase. This finding could potentially be attributed to the notion that the discourse surrounding CCS is primarily situated within the socio-economic realm rather than its capacity for climate mitigation. Consequently, it is plausible that younger individuals are more inclined to endorse the technology in comparison to their older counterparts. Yang et al. (2016) also observed a negative relationship between age and acceptance of CCS. The common belief that people become more conservative as they age provides a possible rationale.

The predictive power of household size in relation to CCS acceptance is small. The acceptance ratings of CCS plant scenarios among respondents are positively correlated with an increase in household size. This is evidenced by an increase of 0.002 scale points. A similar analysis by Dütschke et al. (2016) confirms that there exists a positive correlation between the number of individuals within a household and the acceptance of CCS, particularly in cases where the source of CO_2 emissions comes from coal combustion. Finally, the results in Table 5 above indicate that there is no statistically significant impact on the acceptance of CCS scenario plants in relation to the education level and household income of respondents. This result align with the findings of Yang et al. (2016).

Effects of other Respondent Characteristics on CCS Acceptance

In addition to the socio-demographic model, knowledge about the technology, perceptions of its benefits and risks, and trust in institutions are also potential drivers of acceptance of CCS plants, as has been shown in related literature (Chewinski et al., 2023; Howell et al., 2019; Liebe & Dobers, 2020; Mooney et al., 2022). The socio-demographic model (model 3) was therefore extended to include these variables to get the final model specification (model 4). In order to comprehensively assess the respondents' knowledge, trust, and attitudes towards CCS, as well as various environmental variables, a series of questions were incorporated into the survey for each of the aforementioned factors. The inclusion of numerous highly correlated variables in the model poses the challenge of multi-collinearity and overfitting. To address this issue of multi-collinearity (and overfitting) and attain parsimony in the model specification, the study utilised a widely recognised method of dimensionality reduction known as principal component analysis (PCA). Principal components (PCs) are a linear combination of the original variables. As such, all the original variables are still utilised instead of a subset of them. PCs with the highest eigenvalues (greater than unity) were included in the regression. Table 14 in the appendix shows the results of the PCA. The Kaiser-Meyer-Olkin test for sampling adequacy shows values above 0.60. This statistic measures the proportion of variance among the variables that might be common variance and, hence, implies that the samplings are adequate and satisfactory for the PCA.

As shown in Table 5 above, the coefficient of self-reported support for CCS is highly significant and robust in influencing acceptance of CCS plant scenarios. An increase in self-reported support for CCS leads to a 0.894 scale point increase in CCS plant scenario acceptance. Initially, this may appear as two facets of an identical coin, thereby appearing insignificant in the analysis. However, situating it within the debates surrounding CCS exposes significant insights. By disentangling the economic incentives associated with the technology from its potential to mitigate climate change, one can discern distinctions between the factors that motivate support for the technology and those that drive its acceptance, particularly when considering its siting within an individual's locality. Examining the relationship between the perceptions of benefits and risks associated with CCS among respondents and their acceptance of CCS plant scenarios may provide clarity on this matter.

The acceptance of CCS scenarios is significantly influenced by the objective knowledge of respondents regarding the risks associated with seismicity caused by CCS. On average, respondents who possess insufficient objective knowledge regarding the risks of CCS-induced seismic activity tend to rate CCS plant scenarios 0.163 scale points higher than those who possess accurate knowledge. The significance of this matter lies in the discrepancy between the general public's perception of induced seismicity resulting from CCS and the scientific reality. Based on scientific evidence, the likelihood of CCS inducing seismic activity that is felt on the earth's surface is extremely low (Larkin et al., 2019). However, the mere reference to seismic activity elicits a sense of anxiety. In the same vein, perceptions about the general risks of CCS (such as CO_2 leakage, seismicity, promoting CO_2 emissions, and profit interest) are also negatively correlated with acceptance of CCS plant scenarios. Specifically, an increase in individuals' perceptions about the risks of CCS decreases their average rating of CCS plant scenarios by 0.285 scale points. This result is in line with the findings of Wallquist et al. (2010) and Wennersten et al. (2015). Intriguingly, the perception of benefits associated with CCS (e.g., decreasing CO_2, promoting economic growth, benefiting the environment, and being a cheaper option) is statistically insignificant in predicting the level of public acceptability of CCS plant scenarios.

Furthermore, there exists a positive correlation between possessing a thorough understanding of CCS and the degree to which it is embraced as a viable technology for mitigating climate change. To holistically capture respondents' knowledge of the technology, several questions were asked, such as the possibility of groundwater contamination, CO_2 leakage, induced seismicity, storage capacity, viability of the technology, and the place where CO_2 will be stored underground. The results indicate that an increase in individuals understanding of the technology on average increases their acceptance of CCS plant scenarios by 0.296 scale points. In their analysis, Pianta et al. (2021) demonstrate that individuals who possess knowledge of CCS tend to have the perception that it's societal and climate change-related benefits are greater. However, it is important to note that this does not necessarily result in a corresponding increase in acceptance, as previously mentioned. It is plausible that a higher understanding of the technology may lead to a reduction in perceived risks, thereby resulting in greater levels of acceptance of the technology.

Moreover, the perception of individuals regarding the risks associated with environmental issues (such as glyphosate usage, mobile towers, wind turbines, antibiotics, pests/parasites, crime/violence, drugs, ozone depletion, climate change, and induced seismicity) tends to adversely affect their acceptance of CCS. Individuals with higher perceived risks associated with these environmental phenomena, on average, tend to rate CCS scenario plants 0.163 scale points lower. These findings reiterate the argument that an individual's perception of risks significantly impacts their willingness to embrace CCS as a technology for mitigating climate change (Peridas et al., 2021).

Finally, the acceptance of CCS is found to have a negative correlation with trust in federal government energy regulatory and monitoring institutions. Specifically, an increase in respondents' trust in federal government energy regulators decreases their acceptance rating of CCS scenario plants by 0.420 scale points. At first glance, this phenomenon may seem counterintuitive. However, upon closer examination, it becomes evident that the underlying cause is primarily rooted in the level of confidence individuals have in the federal and provincial governments. The extent to which people trust government energy organisations serves as an indicator of their faith in these entities' capacity to proficiently handle energy-related issues (Stretesky et al., 2023; Truong et al., 2019; Yang et al., 2016). Due to the complexity of CCS as an energy technology, it may only be appropriate to delegate monitoring and regulatory obligations to institutions that have a high level of public trust. However, the negative relationship between trust in government energy regulators and acceptance of proposed scenarios for CCS plants can be attributed to the overwhelming influence of multinational corporations in the oil and gas sector and the prevailing public perceptions regarding the industry's involvement in promoting the CCS technology.

5.0 Conclusion and Policy Implications

The results of CCS research and development have shown that the technology is not only ready but essential for reducing the worst effects of climate change. The public and the economy are putting more pressure on leaders to follow through on their promises to take measures to slow climate change. However, public opinions of the technology are cause for concern since they demonstrate that the execution of CCS projects has been delayed and that considerable challenges persist in linking the promise of CCS to the investment and deployment of CCS facilities. It is still painfully obvious that CCS implementation is falling short of expectations (Martin-Roberts et al., 2021).

A recent analysis of CCS/CCUS policy by the International CCS Knowledge Centre showed that the Government of Canada's 2023 budget has measures to promote large-scale CCS/CCUS projects. However, the analysis noted that Canada's policy framework is missing important details that are needed to encourage private-sector investment (International CCS Knowledge Centre, 2023). The risk assessment and risk management of CCS in Canada centre on three key areas: government and industry factors, environmental risk factors, and socio-economic factors. The socio-economic considerations include several elements, such as the public's opinions of the risks and benefits associated with CCS, the economic costs involved, the availability of information, effective communication strategies, the engagement of stakeholders, and the social and public acceptance of CCS, including the use of decision support tools to facilitate the decision-making process (Larkin et al., 2019). Our experiment explored CCS plant attributes that influence individuals' acceptance of the technology. The paper documents that cross-border imports of CO_2 for storage have the strongest effect on CCS plant scenario acceptance, indicating a lower preference for CO_2 trading between countries. Canada currently holds a share of approximately 15 percent in the global capacity for CCS/CCUS, which amounts to roughly seven million tonnes of CO_2 annually. It is worth noting that this contribution is significant considering that Canada's CO_2 emissions constitute less than two percent of the global total emissions (IEA, 2022).

Our analysis shows that the level of acceptance of CCS plants is contingent upon the provision of compensation, as those affected by such facilities are willing to tolerate a certain level of risk in return for fair remuneration. A proper incorporation of compensation, communication, information sharing, and transparency into the design of CCS plants will be imperative for augmenting public acceptance in Canada. The significant impact of procedural justice on the degree of societal approval of CCS facilities is also worth mentioning. Our empirical evidence suggests that engaging in national and provincial consultation, as well as seeking input from residents of communities directly impacted by CCS plants, can yield favourable outcomes in terms of fostering acceptance.

Individuals regard climate change as a significant concern because they are aware of the repercussions of global warming and are afraid of the harm it brings to their life, as was discovered by Arlota & de Medeiros Costa (2021), CCA (2019), NAS (2021), and Nordhaus (2019). However, this is not sufficient to encourage people to pay for measures that reduce global warming (Lima et al., 2021). Our results validate the significance of the socio-economic and socio-demographic characteristics of respondents (such as age, gender, household size, and household income) as determinants of their acceptance of CCS as a climate mitigation strategy. Knowledge about the technology, perceptions of its benefits and risks, induced seismicity, and trust in institutions are key drivers of acceptance of CCS plants.

The results of this research have three main policy implications for Canada. First, the results reveal a lower preference for CO_2 cross-border trading due to the global impacts of climate change and localised risks of CCS plants. However, if the correct disposal costs, environmental rules, compensation, monitoring, and compliance framework are in place, people can be persuaded to support the international trading of CO_2. Second, prioritising local firms and services in contracts and providing compensation directly to impacted persons represents a desire for fairness in a proximity-based compensation system, suggesting that people may be willing to tolerate some risk in exchange for their fair share of the pie. Similarly, prioritising communication, information sharing, and transparency in the design of CCS plants is essential to enhancing public acceptance, as some individuals may be willing to accept lower compensation for full access to information. Third, the acceptance of CCS scenarios is significantly influenced by the objective knowledge of respondents regarding the risks associated with seismic activity caused by CCS. Also, perceptions about the general risks of CCS are negatively correlated with acceptance of CCS plant scenarios, while perceptions of the benefits associated with CCS are statistically insignificant in predicting the level of public acceptability of CCS plant scenarios. This implies that possessing a thorough understanding of CCS can lead to a reduction in perceived risks, resulting in greater levels of acceptance. Hence, communication efforts to improve public understanding and acceptance should focus on demystifying the risks of the technology instead of its technicalities and climate mitigation capacity.

There are two limitations inherent in this study that give rise to considerations for future research. First, a series of hypothetical scenarios pertaining to CCS plants were offered to the public, but with the caveat that these scenarios do not include the whole spectrum of potential CCS implementations and associated ramifications. In the context of this research, several elements that might have a significant impact on acceptability, such as the public's perception of the financial implications of energy use and the accompanying cost (Volken et al., 2019), were not comprehensively examined. Moreover, the scenarios presented exhibit a certain level of abstraction and are hypothetical in nature. Hence, the survey results reflect the public's reaction, although potentially divergent from actuality. In addition, it should be noted that the survey findings provide a momentary depiction of the present sentiments held by the general population and should not be extrapolated to predict future trends (Renn, 2015).

Second, the scope of this research was restricted to Canada, limiting the applicability of the findings to a broader context. The significance of norms and values and the perceived salience of the climate change problem exhibit variation across countries and cultures. This means that our results cannot be generalised across countries. Given the broad spectrum of opinions on CCS that have been expressed, it is reasonable to presume that various subsets of the population will have varied perspectives on the topic. Therefore, future studies should concentrate on subgrouping the population to provide more specific policy recommendations. Also, to fully comprehend the potential of cross-border CO_2 storage trade, a cross-national study is required.

References

Aitken, M. (2010). Wind power and community benefits: Challenges and opportunities. *Energy Policy*, *38*(10), 6066–6075. https://doi.org/10.1016/j.enpol.2010.05.062

Anghel, S. (2017). Impact of CCS Communication on the General and Local Public in Romania- Oltenia Region. *Energy Procedia*, *114*(November 2016), 7343–7347. https://doi.org/10.1016/j.egypro.2017.03.1865

Arlota, C., & de Medeiros Costa, H. K. (2021). Climate change, Carbon Capture and Storage (CCS), energy transition, and justice: Where we are now, and where are (should be) we headed? In *Carbon Capture and Storage in International Energy Policy and Law*. INC. https://doi.org/10.1016/B978-0-323-85250-0.00019-0

Arning, K., Offermann-van Heek, J., Linzenich, A., Kaetelhoen, A., Sternberg, A., Bardow, A., & Ziefle, M. (2019). Same or different? Insights on public perception and acceptance of carbon capture and storage or utilization in Germany. *Energy Policy*, *125*(November 2018), 235–249. https://doi.org/10.1016/j.enpol.2018.10.039

Ashworth, P., Boughen, N., Mayhew, M., & Millar, F. (2010). From research to action: Now we have to move on CCS communication. *International Journal of Greenhouse Gas Control*, *4*(2), 426–433. https://doi.org/10.1016/j.ijggc.2009.10.012

Ashworth, P., Sun, Y., Ferguson, M., Witt, K., & She, S. (2019). Comparing how the public perceive CCS across Australia and China. *International Journal of Greenhouse Gas Control*, *86*(May), 125–133. https://doi.org/10.1016/j.ijggc.2019.04.008

Atzmüller, C., & Steiner, P. M. (2010). Experimental vignette studies n survey research. *Methodology*, *6*(3), 128–138. https://doi.org/10.1027/1614-2241/a000014

Auspurg, K., & Hinz, T. (2015a). Multifactorial Experiments in Surveys : Conjoint Analysis, Choice Experiments, and Factorial Surveys. *Experimente in Den Sozialwissenschaften*, *1*(ISBN 978-3-8487-1916-7), 291–315.

Auspurg, K., & Hinz, T. (2015b). Setting Up the Survey. *Factorial Survey Experiments*, 60–84. https://doi.org/10.4135/9781483398075.n4

Auspurg, K., & Jäckle, A. (2017). First Equals Most Important? Order Effects in Vignette-Based Measurement. *Sociological Methods and Research*, *46*(3), 490–539. https://doi.org/10.1177/0049124115591016

Bauer, S., Dahmke, A., & Kolditz, O. (2017). Subsurface energy storage: geological storage of renewable energy—capacities, induced effects and implications. *Environmental Earth Sciences*, *76*(20), 1–4. https://doi.org/10.1007/s12665-017-7007-9

Bellamy, R., & Lezaun, J. (2017). Crafting a public for geoengineering. *Public Understanding of Science*, *26*(4), 402–417. https://doi.org/10.1177/0963662515600965

Bellamy, R., Lezaun, J., & Palmer, J. (2019). Perceptions of bioenergy with carbon capture and storage in different policy scenarios. *Nature Communications*, *10*(1), 1–9. https://doi.org/10.1038/s41467-019-08592-5

Bergesen, H. O., Parmann, G., & Thommessen, O. B. (2019). Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972). In *Yearbook of International Cooperation on Environment and Development 1998–99*. https://doi.org/10.4324/9781315066547-20

Bertram, C., & Merk, C. (2020). Public Perceptions of Ocean-Based Carbon Dioxide Removal: The Nature-Engineering Divide? *Frontiers in Climate*, *2*. https://doi.org/10.3389/fclim.2020.594194

Boroumand, N. (2015). Survey Responses on the Public Perception of Induced Seismicity. *CSEG Recorder*, *40 No. 5*(May 2015), 36–41. https://csegrecorder.com/articles/view/survey-responses-on-the-public-perception-of-induced-seismicity

Bosker, R. S. T. A. B. (2012). Multilevel Analysis: An Introduction to Basic and Applied Multilevel Analysis. *Department of Statistics University of Oxford*. http://www.stats.ox.ac.uk/~snijders/mlbook.htm

Boyd, A. D., Hmielowski, J. D., & David, P. (2017). Public perceptions of carbon capture and storage in Canada: Results of a national survey. *International Journal of Greenhouse Gas Control*, *67*(August), 1–9. https://doi.org/10.1016/j.ijggc.2017.10.010

Brauers, H., & Oei, P. Y. (2020). The political economy of coal in Poland: Drivers and barriers for a shift away from fossil fuels. *Energy Policy*, *144*, 111621. https://doi.org/10.1016/j.enpol.2020.111621

Braun, C. (2017). Not in My Backyard: CCS Sites and Public Perception of CCS. *Risk Analysis*, *37*(12), 2264–2275. https://doi.org/10.1111/risa.12793

Brennan, N., & Van Rensburg, T. M. (2016). Wind farm externalities and public preferences for community consultation in Ireland: A discrete choice experiments approach. *Energy Policy*, *94*, 355–365. https://doi.org/10.1016/j.enpol.2016.04.031

Bruhn, T., Naims, H., & Olfe-Kräutlein, B. (2016). Separating the debate on CO2 utilisation from carbon capture and storage. *Environmental Science and Policy*, *60*, 38–43. https://doi.org/10.1016/j.envsci.2016.03.001

Burgess, J., Harrison, C. M., & Filius, P. (1998). Environmental communication and the cultural politics of environmental citizenship. *Environment and Planning A*, *30*(8), 1445–1460. https://doi.org/10.1068/a301445

Capellán-Pérez, I., De Blas, I., Nieto, J., De Castro, C., Miguel, L. J., Carpintero, Ó., Mediavilla, M., Lobejón, L. F., Ferreras-Alonso, N., Rodrigo, P., Frechoso, F., & Álvarez-Antelo, D. (2020). MEDEAS: A new modeling framework integrating global biophysical and socioeconomic constraints. In *Energy and Environmental Science* (Vol. 13, Issue 3). https://doi.org/10.1039/c9ee02627d

Card, D., Mas, A., Moretti, E., & Saez, E. (2012). Inequality at work: The effect of peer salaries on job satisfaction. In *American Economic Review* (Vol. 102, Issue 6). https://doi.org/10.1257/aer.102.6.2981

Carton, W., Asiyanbi, A., Beck, S., Buck, H. J., & Lund, J. F. (2020). Negative emissions and the long history of carbon removal. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(6), 1–25. https://doi.org/10.1002/wcc.671

CCA. (2019). *Canada's top climate change risks: the expert panel on climate change risks and adaptation potential*. https://cca-reports.ca/wp-content/uploads/2019/07/Report-Canada-top-climate-change-risks.pdf

Chewinski, M., Anders, S., & Parkins, J. R. (2023). Agricultural landowner perspectives on wind energy development in Alberta, Canada: insights from the lens of energy justice and democracy. *Environmental Sociology*, *00*(00), 1–13. https://doi.org/10.1080/23251042.2023.2247627

Choi, J., & Hannafin, M. (1995). Situated cognition and learning environments. *Educational Technology Research and Development*, *43*(2), 53–69.

ChoiceMetrics. (2014). *NGENE 1.1. 2 User Manual and Reference Guide: the cutting edge in experimental design*. Choice Metrics.

CICC. (2021). *CANADA'S NET ZERO FUTURE: Finding our way in the global transition.* 131.

Cox, E., Spence, E., & Pidgeon, N. (2020). Public perceptions of carbon dioxide removal in the United States and the United Kingdom. *Nature Climate Change*, *10*(8), 744–749. https://doi.org/10.1038/s41558-020-0823-z

Cvetković, V. M., Öcal, A., Lyamzina, Y., Noji, E. K., Nikolić, N., & Milošević, G. (2021). Nuclear power risk perception in serbia: Fear of exposure to radiation vs. social benefits. *Energies*, *14*(9). https://doi.org/10.3390/en14092464

Dalla Longa, F., Detz, R., & van der Zwaan, B. (2020). Integrated assessment projections for the impact of innovation on CCS deployment in Europe. *International Journal of Greenhouse Gas Control*, *103*. https://doi.org/10.1016/j.ijggc.2020.103133

David, J., & Herzog, H. (2000). The Cost of Carbon Capture. *Energy*, 13–16. http://sequestration.mit.edu/pdf/David_and_Herzog.pdf

David, J. L., & Andrew, J. W. (2006). SOCIAL ATOMISM, HOLISM, AND TRUST. *Academy of Management Review*, *31*(2), 386–408.

Davidson, D. J., Rollins, C., Lefsrud, L., Anders, S., & Hamann, A. (2019). Just don't call it climate change: Climate-skeptic farmer adoption of climate-mitigative practices. *Environmental Research Letters*, *14*(3). https://doi.org/10.1088/1748-9326/aafa30

Dehghani-Sanij, A. R., Tharumalingam, E., Dusseault, M. B., & Fraser, R. (2019). Study of energy storage systems and environmental challenges of batteries. *Renewable and Sustainable Energy Reviews*, *104*(November 2018), 192–208. https://doi.org/10.1016/j.rser.2019.01.023

Démuth, A. (2012). Perception Theories. In *Applications of Case Study Research* (Issue 4). http://issafrica.org/crimehub/uploads/3f62b072bd80ab835470742e71a0fcb5.pdf%5Cnhttp://www.cdc.gov/ViolencePrevention/pdf/SchoolViolence_FactSheet-a.pdf%5Cnwww.sace.org.za

Dixon, T., & Birchenough, A. (2021). *Exporting CO2 for Offshore Storage -The London Protocol's Export Amendment*. *March*.

Dixon, T., McCoy, S. T., & Havercroft, I. (2015). Legal and Regulatory Developments on CCS. *International Journal of Greenhouse Gas Control*, *40*, 431–448. https://doi.org/10.1016/j.ijggc.2015.05.024

Dohmen, T., Willrodt, J., & Willrodt, J. (2018). *Willingness to Take Risk : The Role of Risk Conception and Optimism Willingness to Take Risk : The Role of Risk Conception and Optimism*. *DISCUSSION PAPER SERIES 11642*.

Dowd, A. M., Ashworth, P., Rodriguez, M., & Jeanneret, T. (2012). CCS in the media: An analysis of international coverage. *Energy and Environment*, *23*(2), 283–298. https://doi.org/10.1260/0958-305X.23.2-3.283

Dütschke, E., Wohlfarth, K., Höller, S., Viebahn, P., Schumann, D., & Pietzner, K. (2016). Differences in the public perception of CCS in Germany depending on CO2 source, transport option and storage location. *International Journal of Greenhouse Gas Control*, *53*, 149–159. https://doi.org/10.1016/j.ijggc.2016.07.043

Ebbes, P., Böckenholt, U., & Wedel, M. (2004). Regressor and random-effects dependencies in multilevel models. *Statistica Neerlandica*, *58*(2), 161–178. https://doi.org/10.1046/j.0039-0402.2003.00254.x

Edwards, R. W. J., & Celia, M. A. (2018). Infrastructure to enable deployment of carbon capture, utilization, and storage in the United States. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(38), E8815–E8824. https://doi.org/10.1073/pnas.1806504115

Elzahabi, M., & Yong, R. N. (2001). pH influence on sorption characteristics of heavy metal in the vadose zone. *Engineering Geology*, *60*(1–4), 61–68. https://doi.org/10.1016/S0013-7952(00)00089-2

Evensen, D., Varley, A., Whitmarsh, L., Devine-Wright, P., Dickie, J., Bartie, P., Napier, H., Mosca, I., Foad, C., & Ryder, S. (2022). Effect of linguistic framing and information provision on attitudes towards induced seismicity and seismicity regulation. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-15448-4

Evensen, D., Whitmarsh, L., Devine-Wright, P., Dickie, J., Bartie, P., Foad, C., Bradshaw, M., Ryder, S., Mayer, A., & Varley, A. (2023). Growing importance of climate change beliefs for attitudes towards gas. *Nature Climate Change*, *13*(3), 240–243. https://doi.org/10.1038/s41558-023-01622-7

Fang, Y., Yin, J., & Wu, B. (2018). Climate change and tourism: a scientometric analysis using CiteSpace. *Journal of Sustainable Tourism*, *26*(1), 108–126. https://doi.org/10.1080/09669582.2017.1329310

Federico d'Amore, Lovisotto, L., & Bezzo, F. (2020). Introducing social acceptance into the design of CCS supply chains: A case study at a European level. *Journal of Cleaner Production*, *249*, 119337. https://doi.org/10.1016/j.jclepro.2019.119337

Ferguson, B., & van Gent, D. (2017). A Multi-level, Multi-platform Approach to Communications on the South West Hub CCS Project. *Energy Procedia*, *114*(November 2016), 7260–7275. https://doi.org/10.1016/j.egypro.2017.03.1858

Figueroa, J. D., Fout, T., Plasynski, S., McIlvried, H., & Srivastava, R. D. (2008). Advances in CO2 capture technology-The U.S. Department of Energy's Carbon Sequestration Program. *International Journal of Greenhouse Gas Control*, *2*(1), 9–20. https://doi.org/10.1016/S1750-5836(07)00094-1

Firestone, J., & Kirk, H. (2019). A strong relative preference for wind turbines in the United States among those who live near them. *Nature Energy*, *4*(4), 311–320. https://doi.org/10.1038/s41560-019-0347-9

Frey, R., Richter, D., Hertwig, R., & Mata, R. (2021). Identifying robust correlates of risk preference : A systematic approach using specification curve analysis. *Personality and Social Psychology*, *120*, 538–557.

Gabrielli, P., Gazzani, M., & Mazzotti, M. (2020). The Role of Carbon Capture and Utilization, Carbon Capture and Storage, and Biomass to Enable a Net-Zero-CO2 Emissions Chemical Industry. *Industrial and Engineering Chemistry Research*, *59*(15), 7033–7045. https://doi.org/10.1021/acs.iecr.9b06579

García, J. H., Cherry, T. L., Kallbekken, S., & Torvanger, A. (2016). Willingness to accept local wind energy development: Does the compensation mechanism matter? *Energy Policy*, *99*, 165–173. https://doi.org/10.1016/j.enpol.2016.09.046

Gibbins, J. O. N. (2019). *CCS – From an Oil Crisis to a Climate Crisis Response*. *26*, 559–562.

Gonzalez, A., Mabon, L., & Agarwal, A. (2021). Who wants North Sea CCS, and why? Assessing differences in opinion between oil and gas industry respondents and wider energy and environmental stakeholders. *International Journal of Greenhouse Gas Control*, *106*(February), 103288. https://doi.org/10.1016/j.ijggc.2021.103288

Gough, C., & Mander, S. (2019). Beyond Social Acceptability: Applying Lessons from CCS Social Science to Support Deployment of BECCS. *Current Sustainable/Renewable Energy Reports*, *6*(4), 116–123. https://doi.org/10.1007/s40518-019-00137-0

Greene, W. H., Harris, M. N., Knott, R. J., & Rice, N. (2021). Specification and testing of hierarchical ordered response models with anchoring vignettes. *Journal of the Royal Statistical Society. Series A: Statistics in Society*, *184*(1), 31–64. https://doi.org/10.1111/rssa.12612

Grilli, L., & Rampichini, C. (2011). The role of sample cluster means in multilevel models a view on endogeneity and measurement error issues. *Methodology*, *7*(4), 121–133. https://doi.org/10.1027/1614-2241/a000030

Grilli, L., & Rampichini, C. (2015). Specification of random effects in multilevel models: a review. *Quality and Quantity*, *49*(3), 967–976. https://doi.org/10.1007/s11135-014-0060-5

Gupta, B., & Sen, S. K. (2019). Carbon capture usage and storage with scale-up: Energy finance through bricolage deploying the co-integration methodology. *International Journal of Energy Economics and Policy*, *9*(6), 146–153. https://doi.org/10.32479/ijeep.8104

Haemmerli, L., & Stauffacher, M. (2020). The Neglected Role of Risk Mitigation Perception in the Risk Governance of Underground Technologies— The Example of Induced Seismicity.

International Journal of Disaster Risk Science, *11*(5), 630–639. https://doi.org/10.1007/s13753-020-00298-3

Hasan, M. A., Nahiduzzaman, K. M., & Aldosary, A. S. (2018). Public participation in EIA: A comparative study of the projects run by government and non-governmental organizations. *Environmental Impact Assessment Review*, *72*(November 2017), 12–24. https://doi.org/10.1016/j.eiar.2018.05.001

Heyes, A., & Urban, B. (2019). The economic evaluation of the benefits and costs of carbon capture and storage. *International Journal of Risk Assessment and Management*, *22*(3–4). https://doi.org/10.1504/IJRAM.2019.103337

Hoen, B., Firestone, J., Rand, J., Elliot, D., Hübner, G., Pohl, J., Wiser, R., Lantz, E., Haac, T. R., & Kaliski, K. (2019). Attitudes of U.S. Wind Turbine Neighbors: Analysis of a Nationwide Survey. *Energy Policy*, *134*(August), 110981. https://doi.org/10.1016/j.enpol.2019.110981

Holeczek, N. (2019). Hazardous materials truck transportation problems: A classification and state of the art literature review. *Transportation Research Part D: Transport and Environment*, *69*(March), 305–328. https://doi.org/10.1016/j.trd.2019.02.010

Holz, F., Scherwath, T., Crespo del Granado, P., Skar, C., Olmos, L., Ploussard, Q., Ramos, A., & Herbst, A. (2021). A 2050 perspective on the role for carbon capture and storage in the European power system and industry sector. *Energy Economics*, *104*(July). https://doi.org/10.1016/j.eneco.2021.105631

Howell, E. L., Wirz, C. D., Brossard, D., Scheufele, D. A., & Xenos, M. A. (2019). Seeing through risk-colored glasses: Risk and benefit perceptions, knowledge, and the politics of fracking in the United States. *Energy Research and Social Science*, *55*(May), 168–178. https://doi.org/10.1016/j.erss.2019.05.020

IEA. (2008). CO2 Capture and Storage: A key carbon abatement option. In *Energy Technology Analysis* (Vol. 9789264041). https://doi.org/10.1787/9789264041417-en

IEA. (2021a). Global Energy Review 2021 – Analysis - IEA. *International Energy Agency*.

IEA. (2021b). Global Energy Review 2021: Assessing the effects of economic recoveries on global energy demand and CO2 emissions in 2021. *Global Energy Review*. https://doi.org/10.1787/90c8c125-en

IEA. (2022). CO2 Emissions in 2022. Retrieved September 02, 2023, from https://www.iea.org/reports/co2-emissions-in-2022.

International CCS Knowledge Centre. (2023). Canadian CCUS policy requires further detail to support advancing projects. Retrieved August 19, 2023, from https://ccsknowledge.com/news/canadian-ccus-policy-requires-further-detail-to-support-advancingprojects#:~:text=Canada%20has%20pledged%20to%20cut,tonnes%20per%20year%20by%202030.

IPCC. (2005). *Special Report on Carbon Dioxide Capture and Storage* (M. Bert, Metz; Ogunlade, Davidson; Heleen de, Coninck; Manuela, Loos; Leo, Ed.). CAMBRIDGE UNIVERSITY PRESS. http://www.ipcc.ch/pdf/special -reports/srccs/srccs_wholereport.pdf.%0A

IPCC. (2018). GLOBAL WARMING OF 1.5 °C an IPCC special report on the impacts of global. *Ipcc*, *October 2018*.

IPCC. (2021). Technical Summary. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *Climate Change 2021: The Physical Science Basis*.

IPCC. (2022). An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development,. In *Cambridge University Press* (Vol. 4, Issue 1). https://doi.org/10.1017/9781009157940

Jacquet, J. B. (2012). Landowner attitudes toward natural gas and wind farm development in northern Pennsylvania. *Energy Policy*, *50*, 677–688. https://doi.org/10.1016/j.enpol.2012.08.011

Kácha, O., Vintr, J., & Brick, C. (2022). Four Europes: Climate change beliefs and attitudes predict behavior and policy preferences using a latent class analysis on 23 countries. *Journal of Environmental Psychology*, *81*(September 2021). https://doi.org/10.1016/j.jenvp.2022.101815

Kahlor, L. A., Yang, J., Li, X., Wang, W., Olson, H. C., & Atkinson, L. (2020). Environmental Risk (and Benefit) Information Seeking Intentions: The Case of Carbon Capture and Storage in Southeast Texas. *Environmental Communication*, *14*(4), 555–572. https://doi.org/10.1080/17524032.2019.1699136

Keeling, R. F., Manning, A. C., & Dubey, M. K. (2011). The atmospheric signature of carbon capture and storage. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *369*(1943), 2113–2132. https://doi.org/10.1098/rsta.2011.0016

Kellenberg, D. (2015). The economics of the international trade of waste. *Annual Review of Resource Economics*, *7*(1), 109–125. https://doi.org/10.1146/annurev-resource-100913-012639

Kerr, S., Johnson, K., & Weir, S. (2017). Understanding community benefit payments from renewable energy development. *Energy Policy*, *105*(February), 202–211. https://doi.org/10.1016/j.enpol.2017.02.034

Kim, J. S., & Frees, E. W. (2007). Multilevel modeling with correlated effects. *Psychometrika*, *72*(4), 505–533. https://doi.org/10.1007/s11336-007-9008-1

Koelbl, B. S., van den Broek, M. A., Faaij, A. P. C., & van Vuuren, D. P. (2014). Uncertainty in Carbon Capture and Storage (CCS) deployment projections: A cross-model comparison exercise. *Climatic Change*, *123*(3–4). https://doi.org/10.1007/s10584-013-1050-7

Krause, R. M., Carley, S. R., Warren, D. C., Rupp, J. A., & Graham, J. D. (2014). "Not in (or under) my backyard": Geographic proximity and public acceptance of carbon capture and storage facilities. *Risk Analysis*, *34*(3), 529–540. https://doi.org/10.1111/risa.12119

Kübler, D., Schmid, J., & Stüber, R. (2018). Gender Discrimination in Hiring Across Occupations: A Nationally-Representative Vignette Study. *Labour Economics*, *55*(June 2017), 215–229. https://doi.org/10.1016/j.labeco.2018.10.002

Lackner, K., & Jospe, C. (2017). Climate Change is a Waste Management Problem | Issues in Science and Technology. *ISSUES in Science and Technology*, 83–89. https://issues.org/climate-change-waste-management-problem/

Lackner, K. S., & Brennan, S. (2009). Envisioning carbon capture and storage: Expanded possibilities due to air capture, leakage insurance, and C-14 monitoring. *Climatic Change*, *96*(3), 357–378. https://doi.org/10.1007/s10584-009-9632-0

Larkin, P., Leiss, W., Arvai, J., Dusseault, M., Fall, M., Gracie, R., Heyes, A., & Krewski, D. (2019). An integrated risk assessment and management framework for carbon capture and storage: A Canadian perspective. *International Journal of Risk Assessment and Management*, *22*(3–4). https://doi.org/10.1504/IJRAM.2019.103336

Leung, D. Y. C., Caramanna, G., & Maroto-Valer, M. M. (2014). An overview of current status of carbon dioxide capture and storage technologies. *Renewable and Sustainable Energy Reviews*, *39*, 426–443. https://doi.org/10.1016/j.rser.2014.07.093

Liddick, D. (2010). The traffic in garbage and hazardous wastes: An overview. *Trends in Organized Crime*, *13*(2–3), 134–146. https://doi.org/10.1007/s12117-009-9089-6

Liebe, U., Bartczak, A., & Meyerhoff, J. (2017). A turbine is not only a turbine: The role of social context and fairness characteristics for the local acceptance of wind power. *Energy Policy*, *107*(May), 300–308. https://doi.org/10.1016/j.enpol.2017.04.043

Liebe, U., & Dobers, G. M. (2019). Decomposing public support for energy policy: What drives acceptance of and intentions to protest against renewable energy expansion in Germany? *Energy Research and Social Science*, *47* (August 2018), 247–260. https://doi.org/10.1016/j.erss.2018.09.004

Liebe, U., & Dobers, G. M. (2020). Measurement of fairness perceptions in energy transition research: A factorial survey approach. *Sustainability (Switzerland)*, *12*(19), 1–14. https://doi.org/10.3390/su12198084

Lienhoop, N. (2018). Acceptance of wind energy and the role of financial and procedural participation: An investigation with focus groups and choice experiments. *Energy Policy*, *118*(April), 97–105. https://doi.org/10.1016/j.enpol.2018.03.063

Lima, P. R., Pereira, A. A. M., Chaves, G. de L. D., & Meneguelo, A. P. (2021). Environmental awareness and public perception on carbon capture and storage (CCS) in Brazil. *International Journal of Greenhouse Gas Control*, *111*(August). https://doi.org/10.1016/j.ijggc.2021.103467

Liu, H., Tellez, B. G., Atallah, T., & Barghouty, M. (2012). The role of CO2 capture and storage in Saudi Arabia's energy future. *International Journal of Greenhouse Gas Control*, *11*, 163–171. https://doi.org/10.1016/j.ijggc.2012.08.008

Lokuge, N., Phillips, J., Anders, S., & van der Baan, M. (2023). Human-induced seismicity and the public acceptance of hydraulic fracturing: A vignette experiment. *Extractive Industries and Society*, *15*(August), 101335. https://doi.org/10.1016/j.exis.2023.101335

L'Orange Seigo, S., Dohle, S., & Siegrist, M. (2014). Public perception of carbon capture and storage (CCS): A review. *Renewable and Sustainable Energy Reviews*, *38*, 848–863. https://doi.org/10.1016/j.rser.2014.07.017

L'Orange Seigo, S., Wallquist, L., Dohle, S., & Siegrist, M. (2011). Communication of CCS monitoring activities may not have a reassuring effect on the public. *International Journal of Greenhouse Gas Control*, *5*(6), 1674–1679. https://doi.org/10.1016/j.ijggc.2011.05.040

Løvseth, S. W., Arellano, Y., Deng, H., Finotti, F., Jukes, E., & Bottino, G. (2021). Enabling CCS via fiscal metering. *TCCS-11, Trondheim COnference on CO2 Capture, Transport and Storage*, *June*, 474–481.

Martin-Roberts, E., Scott, V., Flude, S., Johnson, G., Haszeldine, R. S., & Gilfillan, S. (2021). Carbon capture and storage at the end of a lost decade. *One Earth*, *4*(11), 1569–1584. https://doi.org/10.1016/j.oneear.2021.10.002

Mehdi, F., Aurelio, F., & Massimo, F. (2020). Economies of Scale and Scope in Multi-Utilities. *International Association for Energy*, *29*(4), 123–143.

Merk, C., Nordø, Å. D., Andersen, G., Lægreid, O. M., & Tvinnereim, E. (2022). Don't send us your waste gases: Public attitudes toward international carbon dioxide transportation and storage in Europe. *Energy Research and Social Science*, *87*(May 2021). https://doi.org/10.1016/j.erss.2021.102450

Miller, E., Bell, L., & Buys, L. (2007). Public understanding of carbon sequestration in Australia: socio-demographic predictors of knowledge, engagement and trust. *Australian Journal of Emerging Technologies and Society*, *5*(1).

Mills, S. B., Bessette, D., & Smith, H. (2019). Exploring landowners' post-construction changes in perceptions of wind energy in Michigan. *Land Use Policy*, *82*(May 2018), 754–762. https://doi.org/10.1016/j.landusepol.2019.01.010

Moon, W. K., Kahlor, L. A., & Olson, H. C. (2020). Understanding public support for carbon capture and storage policy: The roles of social capital, stakeholder perceptions, and perceived risk/benefit of technology. *Energy Policy*, *139*(May 2019), 111312. https://doi.org/10.1016/j.enpol.2020.111312

Mooney, R., Boudet, H. S., & Hazboun, S. O. (2022). Risk-benefit perceptions of natural gas export in Oregon. *Local Environment*, *27*(3), 342–356. https://doi.org/10.1080/13549839.2022.2040470

Musall, F. D., & Kuik, O. (2011). Local acceptance of renewable energy-A case study from southeast Germany. *Energy Policy*, *39*(6), 3252–3260. https://doi.org/10.1016/j.enpol.2011.03.017

NAS. (2021). Climate change and global warming: Impacts on crop production. *Genetically Modified Plants*, 283–296. https://doi.org/10.1016/b978-0-12-818564-3.09991-1

NETL. (2007). National carbon sequestration atlas of the United States and Canada. Pittsburgh, PA: National Energy Technology Laboratory. *Oxford University*, *XXX*, 60.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, *109*(6), 1991–2014. https://doi.org/10.1257/aer.109.6.1991

Oltra, C., Sala, R., Solà, R., Di Masso, M., & Rowe, G. (2010). Lay perceptions of carbon capture and storage technology. *International Journal of Greenhouse Gas Control*, *4*(4), 698–706. https://doi.org/10.1016/j.ijggc.2010.02.001

Osazuwa-Peters, M., & Hurlbert, M. (2020). Analyzing Regulatory Framework for Carbon Capture and Storage (CCS) Technology Development: A case study approach. *The Central European Review of Economics and Management*, *4*(1), 107–148. https://doi.org/10.29015/cerem.834

Parkins, J. R., Anders, S., Meyerhoff, J., & Holowach, M. (2021). Landowner acceptance of wind turbines on their land: Insights from a factorial survey experiment. *Land Economics*, 012521-0008R1. https://doi.org/10.3368/le.98.4.012521-0008r1

Parson, E. A., & Keith, D. W. (1998). Fossil Fuels Without CO 2 Emissions Technical Status and Prospects. *Science*, *282*(5391), 1053–1054. https://scholar.harvard.edu/files/davidkeith/files/17.parson.1998.fossilfuelswithoutco2.f.pdf

Pellow, D. (2007). *Resisting Global Toxics: Transnational Movements for Environmental Justice*. 10.7551/mitpress/7479.001.0001

Peridas, G., & Mordick Schmidt, B. (2021). The role of carbon capture and storage in the race to carbon neutrality. *Electricity Journal*, *34*(7), 106996. https://doi.org/10.1016/j.tej.2021.106996

Pianta, S., Rinscheid, A., & Weber, E. U. (2021). Carbon Capture and Storage in the United States: Perceptions, preferences, and lessons for policy. *Energy Policy*, *151*, 112149. https://doi.org/10.1016/j.enpol.2021.112149

Qiong, O. U. (2017). A Brief Introduction to Perception. *Studies in Literature and Language*, *15*(4), 18–28. https://doi.org/10.3968/10055

Renn, O. (2015). Stakeholder and Public Involvement in Risk Governance. *International Journal of Disaster Risk Science*, *6*(1). https://doi.org/10.1007/s13753-015-0037-6

Ringrose, P., Greenberg, S., Whittaker, S., Nazarian, B., & Oye, V. (2017). Building Confidence in CO2 Storage Using Reference Datasets from Demonstration Projects. *Energy Procedia*, *114*(November 2016), 3547–3557. https://doi.org/10.1016/j.egypro.2017.03.1484

Ringrose, P. S. (2018). The CCS hub in Norway: Some insights from 22 years of saline aquifer storage. *Energy Procedia*, *146*, 166–172. https://doi.org/10.1016/j.egypro.2018.07.021

Röck, M., Saade, M. R. M., Balouktsi, M., Rasmussen, F. N., Birgisdottir, H., Frischknecht, R., Habert, G., Lützkendorf, T., & Passer, A. (2020). Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. *Applied Energy*, *258*(October 2019), 114107. https://doi.org/10.1016/j.apenergy.2019.114107

Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., & Schellnhuber, H. J. (2017). A roadmap for rapid decarbonization. *Science*, *355*(6331), 1269–1271. https://doi.org/10.1126/science.aah3443

Role, T., To, C., Of, P., & Marine, T. H. E. (2012). THE LONDON CONVENTION AND PROTOCOL : LONDON CONVENTION What is the London Convention and its Protocol ? *Office*.

Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., Ross, A. S., Milojevic-Dupont, N., Jaques, N., Waldman-Brown, A., Luccioni, A., Maharaj, T., Sherwin, E. D., Mukkavilli, S. K., Kording, K. P., Gomes, C., Ng, A. Y., Hassabis, D., Platt, J. C., … Bengio, Y. (2019). *Tackling Climate Change with Machine Learning*. http://arxiv.org/abs/1906.05433

Rosa, L., Sanchez, D. L., Realmonte, G., Baldocchi, D., & D'Odorico, P. (2021). The water footprint of carbon capture and storage technologies. *Renewable and Sustainable Energy Reviews*, *138*(April 2020), 110511. https://doi.org/10.1016/j.rser.2020.110511

Rossi, P. H. (1979). 14. Vignette analysis: uncovering the normative structure of complex judgments. *Qualitative and Quantitative Social Research: Papers in Honor of Paul F. Lazarsfeld*, *176*.

Rubin, J. (2016). The case for divesting from fossil fuels in Canada. *Centre for International Governance Innovation*, *112*. https://www.cigionline.org/sites/default/files/documents/CIGI Paper no.112web.pdf

Rycroft, L. (2020). *Briefing on the EU Innovation Fund and the Implications for CCUS Projects 1 st Report of the Thematic Working Group on : Policy, Regulation and Public Perception*. *January*, 1–23.

Saito, A., Itaoka, K., & Akai, M. (2019). Those who care about CCS—Results from a Japanese survey on public understanding of CCS-. *International Journal of Greenhouse Gas Control*, *84*(October 2018), 121–130. https://doi.org/10.1016/j.ijggc.2019.02.014

Schwabe, R., & Schmelter, T. (2000). *On Optimal Designs in Random Intercept Models*. *39*, 1–9.

Scott, V., Gilfillan, S., Markusson, N., Chalmers, H., & Haszeldine, R. S. (2013). Last chance for carbon capture and storage. *Nature Climate Change*, *3*(2), 105–111. https://doi.org/10.1038/nclimate1695

Shackley, S., McLachlan, C., & Gough, C. (2004). The public perception of carbon dioxide capture and storage in the UK: Results from focus groups and a survey. *Climate Policy*, *4*(4), 377–398. https://doi.org/10.1080/14693062.2004.9685532

Slovic, P., Flynn, J. H., & Layman, M. (1991). *Perceived Risk, Trust, and the Politics of Nuclear Waste*. 1603–1608.

Spence, A., Poortinga, W., Pidgeon, N., & Lorenzoni, I. (2010). Public perceptions of energy choices: The influence of beliefs about climate change and the environment. *Energy and Environment*, *21*(5), 385–407. https://doi.org/10.1260/0958-305X.21.5.385

Stangeland, A., Slagtern, Å., Rønneberg, R., Eide, L. I., & Melaaen, I. S. (2021). *FROM NATIONAL TO INTERNATIONAL FOCUS – RESULTS AND IMPACTS FROM THE NORWEGIAN NATIONAL RD & D PROGRAMME FOR CCS (CLIMIT)*. 272–276.

Starr, C. (1969). Social Benefit versus Technological Risk Published by : American Association for the Advancement of Science Stable URL : http://www.jstor.org/stable/1727970 Technological Risk. *Science, New Series*, *165*(3899), 1232–1238.

Statistics Canada. (2019). *Canada at a Glance 2019: Education*. https://www150.statcan.gc.ca/n1/pub/12-581-x/2019001/edu-eng.htm

Statistics Canada. (2021a). Census Profile, 2021 Census of Population. *Government of Canada*, 3–5.https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E%0Ahttps://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/search-recherche/lst/results-resultats.cfm?Lang=E&GeoCode=35&Letter=L#letL

Statistics Canada. (2021b). *Population estimates on July 1st, by age and sex*. https://doi.org/https://doi.org/10.25318/1710000501-eng

Statistics Canada. (2022). *Canadian Income Survey*. *400*(March 2020), 1–11. https://www150.statcan.gc.ca/n1/daily-quotidien/220323/dq220323a-eng.htm

Steeneveldt, R., Berger, B., & Torp, T. A. (2006). Co2 capture and storage: Closing the knowing-doing gap. *Chemical Engineering Research and Design*, *84*(9 A), 739–763. https://doi.org/10.1205/cherd05049

Stephanie, S., & Graham, U. (1989). Triangles and Triads. *Operational Research Society*, *42*(8), 673–683.

Stephens, J. C., Bielicki, J., & Rand, G. M. (2009). Learning about carbon capture and storage: Changing stakeholder perceptions with expert information. *Energy Procedia*, *1*(1). https://doi.org/10.1016/j.egypro.2009.02.288

Stretesky, P. B., Short, D., & Stamford, L. (2023). The Role of Institutional Trust in Industry, Government, and Regulators in Shaping Perceptions of Risk Associated with Hydraulic Fracturing in the United Kingdom. *Sociological Perspectives*, *66*(3), 496–522. https://doi.org/10.1177/07311214221125803

Strielkowski, W., Veinbender, T., Tvaronavičienė, M., & Lace, N. (2020). Economic efficiency and energy security of smart cities. *Economic Research-Ekonomska Istrazivanja* , *33*(1), 788–803. https://doi.org/10.1080/1331677X.2020.1734854

Sun, X., Alcalde, J., Bakhtbidar, M., Elío, J., Vilarrasa, V., Canal, J., Ballesteros, J., Heinemann, N., Haszeldine, S., Cavanagh, A., Vega-Maza, D., Rubiera, F., Martínez-Orio, R., Johnson, G., Carbonell, R., Marzan, I., Travé, A., & Gomez-Rivas, E. (2021). Hubs and clusters approach to unlock the development of carbon capture and storage – Case study in Spain. *Applied Energy*, *300*(June). https://doi.org/10.1016/j.apenergy.2021.117418

SurveyEngine. (2023). *Academic-Grade Research Software & Management.* Survey Engine. Accessed September 09, 2022, < https://surveyengine.com/>

Tcvetkov, P., Cherepovitsyn, A., & Fedoseev, S. (2019). Public perception of carbon capture and storage: A state-of-the-art overview. *Heliyon*, *5*(12), e02845. https://doi.org/10.1016/j.heliyon.2019.e02845

Ter Mors, E., Weenig, M. W. H., Ellemers, N., & Daamen, D. D. L. (2010). Effective communication about complex environmental issues: Perceived quality of information about carbon dioxide capture and storage (CCS) depends on stakeholder collaboration. *Journal of Environmental Psychology*, *30*(4), 347–357. https://doi.org/10.1016/j.jenvp.2010.06.001

Terwel, B. W., Harinck, F., Ellemers, N., & Daamen, D. D. L. (2009). Competence-based and integrity-based trust as predictors of acceptance of carbon dioxide capture and storage (CCS). *Risk Analysis*, *29*(8), 1129–1140. https://doi.org/10.1111/j.1539-6924.2009.01256.x

Terwel, B. W., Harinck, F., Ellemers, N., & Daamen, D. D. L. (2011). Going beyond the properties of CO2 capture and storage (CCS) technology: How trust in stakeholders affects public acceptance of CCS. *International Journal of Greenhouse Gas Control*, *5*(2), 181–188. https://doi.org/10.1016/j.ijggc.2010.10.001

Thaler, R. H., & Sunstein, C. R. (2008). Nudge: improving decisions about health. *Wealth, and Happiness*, *6*, 14–38.

Truong, D., Davidson, D. J., & Parkins, J. R. (2019). Context matters: Fracking attitudes, knowledge and trust in three communities in Alberta, Canada. *Extractive Industries and Society*, *6*(4), 1325–1332. https://doi.org/10.1016/j.exis.2019.09.004

Tylecote, A. (2019). Biotechnology as a new techno-economic paradigm that will help drive the world economy and mitigate climate change. *Research Policy*, *48*(4), 858–868. https://doi.org/10.1016/j.respol.2018.10.001

Upham, P., & Roberts, T. (2011). Public perceptions of CCS: Emergent themes in pan-European focus groups and implications for communications. *International Journal of Greenhouse Gas Control*, *5*(5), 1359–1367. https://doi.org/10.1016/j.ijggc.2011.06.005

van Alphen, K., Hekkert, M. P., & Turkenburg, W. C. (2010). Accelerating the deployment of carbon capture and storage technologies by strengthening the innovation system. *International Journal of Greenhouse Gas Control*, *4*(2), 396–409. https://doi.org/10.1016/j.ijggc.2009.09.019

van Alphen, K., Noothout, P. M., Hekkert, M. P., & Turkenburg, W. C. (2010). Evaluating the development of carbon capture and storage technologies in the United States. *Renewable and Sustainable Energy Reviews*, *14*(3), 971–986. https://doi.org/10.1016/j.rser.2009.10.028

Volken, S., Wong-Parodi, G., & Trutnevyte, E. (2019). Public awareness and perception of environmental, health and safety risks to electricity generation: an explorative interview study in Switzerland. *Journal of Risk Research*, *22*(4). https://doi.org/10.1080/13669877.2017.1391320

von Rothkirch, J., & Ejderyan, O. (2021). Anticipating the social fit of CCS projects by looking at place factors. *International Journal of Greenhouse Gas Control*, *110*, 103399. https://doi.org/10.1016/j.ijggc.2021.103399

Walker, C., & Baxter, J. (2017). Procedural justice in Canadian wind energy development: A comparison of community-based and technocratic siting processes. *Energy Research and Social Science*, *29*(February), 160–169. https://doi.org/10.1016/j.erss.2017.05.016

Wallander, L. (2009). 25 years of factorial surveys in sociology: A review. *Social Science Research*, *38*(3), 505–520. https://doi.org/10.1016/j.ssresearch.2009.03.004

Wallquist, L., Visschers, V. H. M., & Siegrist, M. (2010). Impact of knowledge and misconceptions on benefit and risk perception of CCS. *Environmental Science and Technology*, *44*(17), 6557–6562. https://doi.org/10.1021/es1005412

Wang, M., Gong, Y., Wang, S., Li, Y., & Sun, Y. (2021). Promoting support for carbon capture and storage with social norms: Evidence from a randomized controlled trial in China. *Energy Research and Social Science*, *74*(February), 101979. https://doi.org/10.1016/j.erss.2021.101979

Wang, M., Wang, S., Sun, Y., & Li, Y. (2019). Improving Public Acceptance of Carbon Capture and Storage(CCS) in China. *IOP Conference Series: Earth and Environmental Science*, *371*(3). https://doi.org/10.1088/1755-1315/371/3/032071

Wennersten, R., Sun, Q., & Li, H. (2015). The future potential for Carbon Capture and Storage in climate change mitigation - An overview from perspectives of technology, economy and risk. *Journal of Cleaner Production*, *103*, 724–736. https://doi.org/10.1016/j.jclepro.2014.09.023

Weyant, J. (2017). Some contributions of integrated assessment models of global climate change. *Review of Environmental Economics and Policy*, *11*(1), 115–137. https://doi.org/10.1093/reep/rew018

Whitmarsh, L., Xenias, D., & Jones, C. R. (2019). Framing effects on public support for carbon capture and storage. *Palgrave Communications*, *5*(1). https://doi.org/10.1057/s41599-019-0217-x

Wilberforce, T., Olabi, A. G., Sayed, E. T., Elsaid, K., & Abdelkareem, M. A. (2021). Progress in carbon capture technologies. *Science of the Total Environment*, *761*, 143203. https://doi.org/10.1016/j.scitotenv.2020.143203

Witt, K. (2019). *The University of Queensland Surat Deep Aquifer Appraisal Project (UQ-SDAAP) Scoping study for material carbon abatement via carbon capture and storage Supplementary Detailed Report Effects of message framing on the support for carbon capture and* (Issue April).

Wolsink, M. (2006). Invalid theory impedes our understanding: A critique on the persistence of the language of NIMBY. *Transactions of the Institute of British Geographers*, *31*(1), 85–91. https://doi.org/10.1111/j.1475-5661.2006.00191.x

Xenias, D., & Whitmarsh, L. (2018). Carbon Capture & Storage (CCS) and public engagement: expert and public views. *Geophysical Research Abstracts*, *20*, 2018–10076.

Yang, L., Zhang, X., & McAlinden, K. J. (2016). The effect of trust on people's acceptance of CCS (carbon capture and storage) technologies: Evidence from a survey in the People's Republic of China. *Energy*, *96*, 69–79. https://doi.org/10.1016/j.energy.2015.12.044

Zhang, K., Lau, H. C., & Chen, Z. (2022). Regional carbon capture and storage opportunities in Alberta, Canada. *Fuel*, *322*(December 2021), 124224. https://doi.org/10.1016/j.fuel.2022.124224

Chapter Two

Heterogeneity in Public Perceptions of Hydraulic Fracturing: A Latent Class Analysis

1.0 Introduction

With growing public concern about hydraulic fracturing's (HF) impact on environmental quality, local government infrastructure, and human health, the use of this technology to increase domestic production of oil and gas (and jobs) has become increasingly controversial in recent years (Bandelow et al., 2022; Davis & Fisk, 2014; Lits, 2021). Consequently, both the economic and ecological elements of the HF policy challenges have received unprecedented media coverage. HF, also known as fracking, is a non-conventional method of extracting oil and natural gas (Davis & Fisk, 2014; Evensen et al., 2014; O'Connor & Fredericks, 2018; Palliser, 2011; Schafft & Biddle, 2015), that makes natural gas extraction from shale formations economically viable, raising shale gas's reputation as a low-cost, low-carbon coal alternative (Bazilian et al., 2013; Tan et al., 2019). Oil and gas extraction from shale formations by HF has been dominated by the United States (US) and western Canada for decades (Thomas et al., 2017).

However, both in the literature and in policy initiatives, public perception of HF remains a contentious subject. On May 15, 2015, for instance, the governor of Texas, Greg Abbot, signed a policy that forbade communities from blocking HF inside their jurisdictions (Malewitz, 2015), stating that it would preserve private property and promote economic recovery (Choma et al., 2016). In contrast, HF was prohibited in Maryland and New York because of environmental and health concerns (Cama, 2015; Kaplan, 2014). In the same vein, Germany banned HF due to the potential harm it could cause to human health and the environment, while the United Kingdom lifted its ban due to the potential economic benefits (Boudet et al., 2014; Smith-Spark & Jim, 2013; Tost, 2014). More than 50 HF bans have been enacted in Canada and internationally over the last decade, with many of these bans pointing to environmental concerns as their justification (Baka et al., 2019; Hess et al., 2019). While HF is widely used in western Canada (British Columbia and Alberta), currently, there are many moratoriums on its usage in the eastern provinces of Canada (Nova Scotia, New Brunswick, and Quebec) (O'Connor & Fredericks, 2018). While some argue in favour of HF as a viable, clean, and environmentally friendly domestic energy option, there are also those who strongly condemn its ecological repercussions (Popkin et al., 2013).

Although fossil fuels continue to have a significant role within the energy system, there is a growing level of concern among some segments of the public over the extraction of oil and gas, particularly in relation to HF. According to them, most of the world's known fossil fuel reserves must remain underground if global warming is to be limited to 2 °C above pre-industrial levels (McGlade & Ekins, 2015). Major localised concerns about HF include potential risks of water contamination, and induced seismicity as well as social impacts and health effects on Canadians (McGlade & Ekins, 2015; Royal Society, 2012). However, shale gas proponents claim that it is a better "bridge fuel" to a reduced carbon economy since it burns cleaner than coal. According to them, home production might be a means to lessen the country's dependence on imported gas and oil as conventional supplies diminish (Thomas et al., 2017). In addition, Alberta has a greater dependence on fossil fuel extraction for both economic activity and employment compared to other provinces in Canada. Specifically, fossil fuel extraction accounts for 22% of Alberta's economic activity and 6% of its employment (National Energy Board, 2011).

In an effort to address HF environmental concerns, particularly induced seismicity risks, authorities have made concerted efforts to integrate contemporary oil and gas drilling methods within existing regulatory frameworks (Davis & Fisk, 2014); this has the potential to ignite public protests and political upheaval (Bayer & Ovodenko, 2019). It is unclear how seriously western Canada (particularly Alberta) will take the matter of shifting the country's economy away from carbon-intensive sectors, given its prior substantial dependence on fossil fuels (O'Connor & Fredericks, 2018). Public views of the problem are expected to play an enormous role in Canada's transition to a less carbon dependent economy (Thomas, et al., 2017).

Over the last 30 years, academic and policy scholarship in Europe and North America has primarily focused on the public's views of energy technologies (Keeney et al., 1990; Thomas et al., 2017; Wynne, 1983). However, public opinion of HF remains a contested topic in the literature and in legislative attempts. Olive (2016) points out that in Canada, there are five main themes in the HF debate: water contamination, financial gain, danger of unknown consequences, moratoriums, and self-sufficiency in energy production. HF in the Western Canadian Sedimentary Basin (WCSB) has resulted in some induced seismicity; however, the evidence shows that this seismicity is deep, near the reservoir interval, and offers no danger to human health, safety, or the environment (CAPP, 2019). However, using a random effect model with vignette experimental data, Lokuge et al. (2023) pointed out that HF-earthquake dangers pose a significant obstacle to the public's acceptance of HF, regardless of individuals' views on the controversies surrounding the technology.

There are several factors that contribute to the polarisation of public perceptions of the HF technology. As observed by Williams et al. (2017), the current state of knowledge about the technology, its risks, and other possible material ramifications (ranging from global climate change to changes in ordinary lifestyles) are cause for concern. Howell et al. (2019) revealed that politics has a significant role in the perceptions of risks and benefits that people have regarding HF, and those who regard themselves as being informed about HF are more inclined to support it. Concerns about the pollution of water supplies and other environmental repercussions persist among stakeholders, including local governments, homeowners, public health organisations, and environmental organisations (Davis & Fisk, 2014). Several environmental problems, including water contamination and earthquakes, have been connected to the injection of proppants and wastewater during HF (Thomas et al., 2017). However, while some see it as a threat, others see it as a huge opportunity. Funding for medical insurance, welfare services, education, and infrastructure is made possible because of HF's profitability (Mccleary & Coupe, 2022). Public perceptions of energy technologies and energy transitioning are influenced by the political and economic climate of western Canada, notably Alberta, where fossil fuels are extracted using HF (Chewinski et al., 2023).

Surveys generally indicate that a greater number of Canadians are in favour of the development of conventional oil, oil sands, and associated pipelines than are opposed to these activities; nevertheless, there is a significant amount of diversity across different regions and groups in this regard (Anderson & Coletto, 2016; Ekos, 2016). Although Alberta continues to demonstrate stronger support for oil sands and most other non-renewable resource technologies, recent academic research reveals decreased support across a Canada-wide sample for oil sands and oil derived from other sources (Sherren et al., 2019). Evidence like this suggests that the opinions of Canadians about HF are influenced by both the characteristics of individual HF projects and individuals' socioeconomic backgrounds.

To improve our understanding of this contentious subject in energy policy and the related literature, this study employs a survey embedded with a factorial survey experiment to investigate the underlying individuals' heterogeneity that determine their support for or resistance to the HF technology and its use to extract oil and gas. We draw on concepts of NIMBY (Not-In-My-Backyard), environmental pollution, induced-seismicity, energy self-sufficiency, distributive, and procedural justice to investigate the heterogeneity in public perceptions of HF. Few studies have looked at public perceptions of HF in north America (Brunner & Axsen, 2020; Jacquet, 2012; Mccleary & Coupe, 2022; Westlake et al., 2023). However, most of them assumed homogeneity in individuals' underlying characteristics in revealing their preferences (choice sets). Empirical evidence in the energy economics literature, however, suggests that public perceptions of energy technologies are heterogeneous (Borriello et al., 2021; Dallenes et al., 2023; Kácha et al., 2022).

This study, therefore, contributes to the HF literature by looking at the heterogeneity in public perceptions of HF with a specific application of latent class analysis (LCA). This study differs from earlier HF perception studies in that, first, it considers differences across different kinds of people and how these differences impact their perceptions about HF, with a focus on strengthening participation and engagement in local communities to promote more openness, transparency, and a more equitable distribution of information among a wide range of stakeholders with varying and often conflicting interests. Understanding the variations between different groups of people is critical for developing policies that reflect their needs and diversity. Second, the use of a vignette experimental design also distinguishes this study from conventional discrete choice experiments in energy economics, but it follows a line of economic research on discrimination (Kübler et al., 2018), perceptions of fairness (Herz & Taubinsky, 2018), ethical judgements (Ambuehl & Ockenfels, 2017), and social acceptability (Liebe & Dobers, 2019).

The remainder of the chapter is structured as follows: part two examines the technical aspects of HF as well as the body of literature on public perceptions of HF. The third section examines data and techniques. The fourth section contains the findings and discussions. The fifth section wraps up the study and offers policy recommendations.

2.0 Literature Review

Considering the contentious nature of HF within the public and political debates, there exists a considerable body of research that extensively examines the prevailing public perceptions of the technology. In general, there is barely any support for HF in the United States (Thomas et al., 2017), and there is only a small support in the United Kingdom (Evensen et al., 2022; Stedman, Evensen, et al., 2016), China (Tan et al., 2019), and Canada (O'Connor & Fredericks, 2018). The use of HF in Canada, mostly by international corporations, has provoked considerable debates and disputes (Lachapelle et al., 2018).

Public perceptions on the construction and use of HF to extract oil and gas has been studied in the context of induced-seismicity (Lokuge et al., 2023), politics (Choma et al., 2016; Clarke et al., 2016), economic nationalism (Lachapelle et al., 2018), and NIMBYism (Gravelle & Lachapelle, 2015; Jerolmack & Walker, 2018), a bias that can be affected by demographic factors such as age, education, income, and sex, as well as by direct or indirect exposure to the energy sector and, in particular, HF (Boudet et al., 2016; Mooney et al., 2022; Thomas et al., 2017). Studies show that individuals' perceptions of HF are highly polarised because of a wide range of effects, including: contaminating groundwater, or removing too much groundwater (Myers, 2012; Rozell & Reaven, 2012; Steinzor et al., 2013; Warner et al., 2013); causing air pollution and greenhouse gas emissions that contribute to climate change (Howarth et al., 2012; Kemball-Cook et al., 2010; Roy et al., 2014); posing danger to human health (Colborn et al., 2011; Esswein et al., 2013; Kassotis et al., 2014); eroding landscapes and watersheds, interfering with animal habitat and other land uses such as subsistence agriculture, tourism, and ranching (Drohan et al., 2012; Jantz et al., 2014); and prompting seismic activities (Davies et al., 2013; Kim, 2013). Faulty wells, as well as leaks, micro-seismicity, and spills linked with HF activities, are more likely sources of potential environmental damages (Royal Society, 2012).

However, according to other research findings, higher exposure to HF is associated with reduced perceived risks and larger reported benefits (Kriesky et al., 2013; Lachapelle et al., 2014). It is hypothesised that this may be due to the economic benefits accruing to individuals and local communities rather than an actual decrease in perceived risks for people with higher exposure to HF (Boudet et al., 2014). According to Thomas et al. (2017) assessment, the major advantages of HF operations are energy independence and security, economic growth, and job creation, combating climate change, a reliable supply of energy, and lower energy costs. Palliser (2011) argues that HF is beneficial because, since natural gas burns cleaner than coal or oil, it produces less carbon dioxide, nitrous oxide, and sulphur dioxide emissions per unit of energy. The HF sector is thriving and expanding at an incredibly quick pace. In Canada, O'Connor & Fredericks (2018) identified HF benefits such as employment creation, reduced reliance on imported fossil fuels, promotion of energy independence, tax revenue for provincial governments, cheaper energy costs for consumers, and reduction of Canada's carbon footprint.

The research on HF's growth has always focused on weighing the social (fairness) and environmental (pollution) concerns presented by HF against the potential economic benefits of HF, which are often evaluated in terms of local employment and economic activity (Evensen et al., 2014; O'Connor & Fredericks, 2018; Popkin et al., 2013; Thomas et al., 2017). Perception studies in the wind energy literature have mostly focused on the importance of consulting with and compensating people impacted by new energy installations (Brennan & Van Rensburg, 2016;

García et al., 2016; Parkins et al., 2021; Walker & Baxter, 2017). There exists a limited though expanding collection of research that investigates the concept of social licence and trust in relation to political loyalty and the presentation of HF argument within the context of deliberations around the trade-offs between benefits and costs associated with HF.

Stedman et al. (2016) found that in the UK, more HF knowledge was linked to increased support, whereas in the US, knowledge was unrelated to support. Baka et al. (2019) reported that one of the three main public comments in the HF discussion was the lack of scientific understanding of the effects of HF. In contrast, a study by McLaughlin and Cutts (2018) revealed that resistance to HF is motivated by more complex reasons than a lack of understanding and/or NIMBYism. Lachapelle et al. (2018) believes that, given the history of Canadian economic nationalism and the low level of trust Canadians have for American companies, there may be an anti-American bias influencing public opinion in Canada regarding HF, at least in part. The Province of Nova Scotia, for instance, was not ready to accept HF, according to Atherton & Macintosh (2014), owing to a lack of confidence in business and government, as well as a lack of a geographically anchored social licence. Davis & Fisk (2014) observed that people who have a higher level of trust in these institutions are less likely to oppose the construction of new plants in their communities. Others have focused on the stress and anxiety generated by a lack of confidence in government and business regulations and the fear of HF (Willow et al., 2014). Thomas et al. (2017) also noted scepticisms about corporate intentions both in the US and UK, with the majority doubting that the gas/oil and energy firms can be trusted to guarantee that HF is done safely.

According to a nationally representative survey, Albertans are more likely to support HF because they see greater economic rewards and fewer environmental and social consequences (Brunner & Axsen, 2020). However, it is unclear whether the benefits of shale development outweigh the risks:

the benefits are often economic (job creation and socio-economic activity boosts), while the risks are primarily environmental or social (such as effects on water or increased traffic) (Thomas et al., 2017).

There is also a correlation between increased levels of concern for the environment and resistance to HF. According to Axsen's (2014) research on the Northern Gateway pipeline, individuals who see climate change as a major threat are less inclined to support the project, while those who view it as a minor one are more likely to support it. The significance of environmental considerations varies depending on the kind of energy innovations being considered. For instance, studies comparing the pros and cons of renewable and nuclear energy have linked environmental and climate change concerns with preference for the former and opposition to the latter (Spence et al., 2010).

Other studies have shown that the acceptability of energy technology may also be affected by demographic and social variables. For instance, women are more inclined to reject nuclear power plants (Kim et al., 2014), offshore oil drilling (Smith et al., 2010), hazardous waste facilities (Hunter & Leyden, 1995), pipelines (Gravelle & Lachapelle, 2015), and HF (Boudet et al., 2014; Thomas et al., 2017; Truong et al., 2019). According to the existing evidence, senior citizens are also more likely to approve of various energy infrastructure projects, including HF (Boudet et al., 2014; Thomas et al., 2017), pipelines (Gravelle & Lachapelle, 2015), and onshore oil drilling (Klick & Smith, 2010). Again, older Canadians are more likely than younger ones to agree that the oil and gas industry is vital to the country's economy right now and in the future, according to a study conducted by Ekos (2016).

The role of wealth and education is less certain. Regarding the Northern Gateway Pipeline (Axsen, 2014), for instance, there were no statistically significant differences in wealth or education level between groups of respondents who expressed varying degrees of support for the project (Whitfield et al., 2009). Another study found that support for HF was positively correlated with education level but was unrelated to income (Boudet et al., 2014). On the other hand, studies of natural gas drilling in the US have shown that the more educated the population is, the more likely they are to be against the practise of HF (Jacquet, 2012). In Canada, those with higher incomes are more likely to favour unconventional fossil fuel pipelines, see oil and gas energy projects as crucial to the country's economy, and believe that pipelines are the safest route to move oil (Ekos, 2016).

While the studies and existing literature on public perceptions reviewed above offer valuable insights into individuals' perceptions, (Lokuge et al., 2023; Choma et al., 2016; Clarke et al., 2016; Lachapelle et al., 2018; Gravelle & Lachapelle, 2015; Jerolmack & Walker, 2018), it is important to acknowledge the inconsistencies in the evidence, which underscore the limitations of relying solely on surveys to assess support for this technology. This is particularly relevant considering the wide-ranging implications of HF, including global factors such as energy prices, energy self-sufficiency, and climate change, as well as localised concerns such as induced seismicity, pollution, economic benefits, etc. The existence of inconsistencies and the polarised nature of public perceptions of HF suggest that there is heterogeneity in individuals' preferences for this technology. Investigating this heterogeneity in the existing literature on HF would be valuable in enhancing our understanding and resolving the inconsistencies observed in the empirical findings.

This paper, therefore, investigates the factors that contribute to the wide range of public perceptions around HF. A review of the relevant literature and, to the best of our understanding, no LCA using vignette data to investigate public views of HF have been conducted. This study addresses this gap in the literature by using LCA to explore the heterogeneity of public perceptions of HF. Our study places particular emphasis on several key factors that have been shown to have a substantial influence on HF support. These factors include proximity to HF sites, the volume of truck traffic associated with HF operations, the duration of operational activities, the extent of community engagement, the economic advantages derived from HF, the occurrence of induced seismicity, and the socio-demographic characteristics of the affected population. To address the difficulty of untangling the impacts of various intricate decision factors that influence individuals' assessment of HF, we utilise a factorial survey (vignette) experiment (FSE) (Auspurg & Hinz, 2015a). This approach allows us to examine the effects of multiple factors, including proximity, concerns about environmental pollution, perceptions of fairness in consultation and compensation schemes, trust, and the risk of induced seismicity.

When attitudes, social norms, and perceptions are central to the research question, vignette experiments (VE) are preferred over choice experiments (CE) because they highlight the effect of multiple factors on the overall acceptance of a specific scenario (Parkins et al., 2021). Because of the general public's lack of familiarity with HF and the dangers posed by its induced seismicity, a CE method runs the risk of overwhelming respondents and producing inaccurate results (Auspurg & Hinz, 2015a). To avoid these limitations, our VE employs an ordinal rating scale that reduces the likelihood of social-desirability bias and invites respondents to consider the costs, benefits, and equity issues associated with various future HF growth scenarios (Liebe et al., 2020).

Preference heterogeneity is increasingly being investigated using LCA (Borriello et al., 2021; Dallenes et al., 2023; Van Rijnsoever et al., 2015). The use of latent classes (LC) enables the identification of discrete groups with widely divergent preferences. The use of class membership functions permits a more in-depth examination of the elements that determine class membership probability, and therefore, a more precise description of the demographic, behavioural, and attitudinal characteristics of each segment of the population (Motz, 2021).

However, this strategy has not been extensively used in the HF literature. LCA has been used in a variety of scenarios for perception investigations. Qi et al. (2020) used LCA to investigate the impact of the COVID-19 epidemic on patterns of pregnant women's perception of threat and its relationship to mental state. While Read et al. (2021) employed the technique to evaluate public preferences for paying for social care in later life in England. Using a CE data in the energy economics literature, Borriello et al. (2021) used LCA to investigate electricity mix preferences among renewables and non-renewables. However, the application of LCA to vignette data has been mostly unexplored until a recent study conducted by Chewinski et al. (2023), looking at agricultural landowners' perspectives on wind energy development. This study hopes to contribute to this emerging body of research by conducting a LCA with VE data from the development of proposed HF scenarios in western Canada.

Specifically, the objectives of this paper are in threefold; (1) to identify different class profiles in terms of perception and preferences for HF; (2) how different classes evaluate the overall risks and benefits of HF, with a focus on HF-induced earthquake risks; (3) individual characteristics that influence their class memberships. Answers to these questions will create a common foundation for policy and literature debates.

3.0 Study Design

This research pertaining to Canada's oil and gas industry was granted approval by the Research Ethics Board of the University of Alberta (ID: Pro00088384). A web-based questionnaire was initiated on March 11th, 2019, and remained accessible until June 24th, 2019. The study received a total of 1,311 responses, with the majority of the responses originating from the western part of Canada, specifically Alberta.

The recruitment of participants included many strategies, such as reaching out to universities, regional newspapers, and media outlets, in addition to leveraging internet platforms like Facebook. Furthermore, efforts were made to engage local or provincial leaders in order to enhance the visibility and encourage participation in the survey. To mitigate the potential influence of selection bias, "western Canada" was emphasised in the topic and in recruiting participants. The participants that met the criteria were those who were at least 18 years old and self-reported residing in western Canada. The use of recruitment quotas guaranteed that the resultant sample achieved an appropriate level of representativeness in comparison to the Canadian census data for western Canada. It is worth noting that over 70% of our sample reported residing in Alberta. In the survey, the first three digits of each participant's postal code were asked for so that the reliability and validity of the data could be checked. Though replies came in from all around western Canada, the vast majority were from Alberta. Since HF is mostly used in Alberta, this research focuses on this province. This sample fairly represents the population of western Canada; however, it is not considered a random sample because of the difficulty and expense of recruiting members of the general public to take part in a survey for which they were not financially compensated, as is customary for commercial survey firms. See Lokuge et al. (2023) and Phillips (2021) for data and survey details.

3.1 Sample Characteristics

Table 6 (reproduced from Lokuge et al. 2023)) shows the socio-demographic and economic characteristics of the respondents in the sample. The data shows that the majority of the respondents (80.15%) are in their prime working years (25–64 years). Approximately 7.82% are young adults (18–24), 44.05% are adults (25–44), 36.10% are late-adults (45–64), and 9.85% are seniors (65+). The official statistics from Statistics Canada, which put the median age at 41 years old, are quite close to this estimate (Statistics Canada, 2021). However, a study on a similar topic by Lachapelle et al. (2018) reported an average age of 56 years with a standard deviation of 14.85.

In terms of gender, females represented 42.24%, and males 54.39%, while non-binary, transgender, non-identified people represented 4.08%. While women make up 50.7% of the Canadian population over the age of 20 (Statistics Canada, 2021), just 42.24% of those who filled out the survey fell into that demographic. Although this is a smaller number, it is heartening that women make up over a third of the respondents, as interest in energy is often thought to be limited to men.

Participants' educational backgrounds varied widely, from having no college education to holding advanced degrees. The data indicate that almost three quarters (85.96%) of the respondents have completed post-secondary education. This is somewhat higher than the average for Canada, where around 65% of the workforce has completed post-secondary education (Statistics Canada, 2019). However, this might be due to the inclusion of people outside the workforce (seniors).

Table 6: Socio-demographic and Economic Characteristics of the Sample

Variable	Description	Sample (n = 1,311) (Percentages)	Census Benchmark
Age (years)	18 – 24	7.82	5.80
	25 – 44	44.05	29.30
	45 – 64	36.15	40.50
	65+	9.85	14.70
	Prefer not to say	2.13	-
Gender	Male	54.39	50.10
	Female	42.24	49.90
	Other	0.71	-
	Prefer not to say	3.37	-
Level of Education	Graduate degree	20.87	8.40
	Undergraduate degree	31.17	17.50
	College	19.27	21.8
	Technical or trade certificate	14.65	8.70
	High school	11.46	26.70
	No formal education	0.44	-
	Prefer not to say	2.13	-
Work Experience	Energy Industry	33.31	-
	Government	6.40	-
	Consultancy	14.37	-
	Environmental Organisation	9.05	-
	None of the above	36.40	-
	Prefer not to say	0.47	-
Location	Rural	42.04	15.20
	Urban	57.96	84.80

Respondents' work experience also cuts across different industries. Most of the respondents (33.31%) indicated they have work experience in the energy industry. Albertans are known for their oil, so this is to be expected. Aside from those in the energy industry, about 14.37% of the sample works in consulting, 6.40% in the government sector, 9.05% for environmental groups, and 36.40% are employed in other fields. There was a good mix of rural and urban residents in the sample as well. Of those who participated in the survey, more than half (57.96%) reported that they live in the city, while the others (42.04%) stated that they live in rural areas.

3.2 Experimental Approach

Respondents are expected to consider a wide range of decision factors when evaluating possible HF projects, many of which are not immediately quantified, such as monetary payments, seismic risks, noise levels, closeness, and other project features. Choice models and preference causality inferences are more difficult to link when larger social aspects are included. A consequence of this is that a majority of multilevel survey studies separate questions concerning the significance of social factors from questions about preferences (Parkins et al., 2021). Stated preference approaches have a disadvantage in that they can't separate these two aspects of preference elicitation.

Rather than directly measuring beliefs, social norms, and judgements via a single survey item, FSE do so indirectly, focusing on the relevance of related situational factors (Liebe et al., 2020). FSE is an experimental setting where variables or situational qualities are changed in a way that makes it possible to separate the effects of single situational dimensions. When social norms and beliefs are crucial to the research topic, VEs help to highlight the impact of these diverse elements on the acceptability of the technology under investigation (Parkins et al., 2021). However, this has not been explored in any depth in the studies on the public's perception of HF. Individuals' values and beliefs highly influence their ratings of vignette scenarios as either right or wrong, fair or unfair, acceptable or unacceptable, and supportive for or against. These personal values may impact behavioural intentions, according to substantial evidence in the literature, which is why this research applies this theory to examine people's preferences for HF activities labelled with specific vignette attributes (e.g., choice of vignette attributes).

VE may be used to account for these social elements within brief and descriptive scenarios, depending on key decision variables. Individuals that take part in VE research are usually presented with several scenarios and asked to rate each one on the basis of how much they accept, support, or think it's fair. It is possible to identify causal characteristics based on theory-led experiments and contextual elements provided by the researcher by randomising discrete and linked qualities, which are thought to be major predictors of respondents' decision-making (Auspurg & Hinz, 2015). In contrast to stated-preference approaches, VEs do not ask respondents to make choices from which trade-offs are determined. As a result, VEs give an indirect measure of people's judgements of vignette attributes as part of a scenario, where the possibility for social desirability bias is reduced through attribute trade-offs (Auspurg & Jäckle, 2017). To put it another way, VEs can be used to evaluate the relative relevance of a collection of attributes and levels in the evaluation of an experimentally constructed situation (Hainmueller et al., 2015).

This study uses this technique to investigate individuals' preferences for HF activities labelled with various vignette attributes based on strong evidence in the literature that these attributes might influence behavioural intentions. VE analysis allows for the possibility of testing between-respondent variations in their ratings of vignette scenarios (Auspurg & Hinz, 2015). Respondent traits not included in the vignettes are likely moderator factors. These factors may enhance or impede the processes found in VE research in real-world contexts (Auspurg & Hinz, 2015). With the use of LCA, it is possible to identify distinct subgroups with wildly varied preferences. This information can be used to build policies that meet the needs and preferences of a broad spectrum of people and organisations engaging in HF activities.

3.3 Vignette Design

Six attributes were created after an intensive literature review and conversation with knowledgeable industry, regulatory, and academic experts in order to address what seem to be the most relevant variables generating support for or opposition to HF. As shown in Table 7, those six attributes were highlighted and incorporated into the design of the VE. First, to investigate the complicated link between proximity to HF sites and support for HF operations, the location of HF activities (or wells) and their proximity to residences and the community were employed. Depending on the kind of development and the amount of H_2S (hydrogen sulphide) present, Alberta's minimum requirements for wells containing H_2S might be as low as 100 metres away from permanent residences (Alberta Energy Regulator, 2015). According to the regulations in British Columbia, the minimum distance within which a duty to consult is required is 200 metres for pipelines and 1 km for a small wellsite (BC Oil and Gas Commission, 2015). Individuals living close to HF activities may enjoy economic benefits such as employment and an increase in economic activity. However, this also implies high susceptibility to any perceived risks associated with it. The complexity of these interactions will ultimately determine an individual's support for HF activities. This phenomenon is often referred to as the NIMBY effect in the energy economics literature (Liebe & Dobers, 2019; Parkins et al., 2021; Ritchie et al., 2021). Nevertheless, the existing research on HF presents conflicting results about the distance effects of NIMBYism in relation to perceptions of risks and benefits (Czolowski et al., 2017; Popkin et al., 2013; Thomas et al., 2017). The proximity of HF project locations was modelled as “Less than 3 km from the home”. “Between 3 and 15 km from the home”, and “Over 15 km from the home”.

Second, in addition to increasing traffic, travel time, and noise, heavy-duty vehicle traffic on an HF site may potentially lead to accidents. A single HF well might potentially need hundreds to thousands of vehicles to transfer equipment and supplies (DEC, 2011). Truck drivers, on the other hand, will see an increase in demand as a result of this, generating jobs and income for many families. Communities' complaints about energy development and HF are well-documented, and they often centre on noise (and dust) pollution from truck traffic, which may also harm local road infrastructure (Holeczek, 2019; O'Connor & Fredericks, 2018). The number of trucks operating on an HF site was modelled as "Less than 10 heavy equipment trucks per day", "Between 10 and 50 heavy equipment trucks per day" and "Over 50 heavy equipment trucks per day".

Table 7: FSE attributes and attribute levels - HF.

Attribute	**Attribute Level Number**	**Attribute Level**
Proximity	1	Less than 3 km from the home
	2	Between 3 and 15 km from the home
	3	Over 15 km from the home
Trucks	1	Less than 10 heavy equipment trucks per day
	2	Between 10 and 50 heavy equipment trucks per day
	3	Over 50 heavy equipment trucks per day
Time	1	At all hours of the day
	2	Between the hours of 8 am and 8 pm
Consultation	1	Community not informed of plans for operation
	2	Community informed of plans for operation
	3	Directly affected landowners consulted about operation
	4	Full two-way consultation with community in every step of the planning process
Benefits	1	No financial benefits for community
	2	Preferential hiring of local services and employees
	3	Annual cash grants between $10k and $25k donated to community
	4	Fully funded community project donated to community
Seismicity	1	None-existent
	2	Too small to be felt
	3	Persistent and repeating, but too small to cause structural damage
	4	Infrequent, but large enough to potentially cause moderate structural damage

Third, over the course of an HF well's lifespan, the number of hours worked might fluctuate widely. Although homeowners may be able to accept HF activities in and around their neighbourhoods, some peculiar times and durations of work may be greatly resented by those who live nearby. In many cases, working throughout the day and during regular business hours is tolerated by the public. Extending work hours beyond some important points of time in the day may be met with resistance. A report by Mccleary & Coupe (2022) indicates that inhabitants around HF sites claim that HF operations are keeping them awake at night; a lot of hammering, rumbling, and roaring noises can be heard down at the site at night, which makes it difficult to sleep. Longer workdays do, however, have the extra advantage of giving employees greater value for their time. Therefore, individuals who live nearby may support HF activities as a trade-off between comfort and a better income. The time attribute was modelled as working "At all hours of the day" and "Between the hours of 8 am and 8 pm".

Fourth, fairness in the planning process is measured by how well the public is included, how openly information is shared, and how much influence the public has on where an HF project is located. According to Li et al. (2013), participation is a useful way to settle disputes among project stakeholders, prioritising their needs and optimising their mutual satisfaction via their involvement. Randeree & Faramawy (2011), however, argue that in order to expedite the participatory process, decision-makers often try to avoid it, which is naive because conflict is usually rooted in the differences between different stakeholders as well as their differing cultural values, beliefs, and behaviours. A person's willingness to support HF may be swayed if there is enough public consultation before, during, and after the implementation of HF initiatives. Research in the renewable energy field has consistently shown that enhanced procedural justice, specifically through the inclusion of local communities in decision-making processes, has a significant impact on the perceived fairness of these processes (Brennan & Van Rensburg, 2016; Liebe & Dobers, 2019; Parkins et al., 2021). The attribute, consultation, was modelled with four levels, “Community not informed of plans for operation”, “Community informed of plans for operation”, “Directly affected landowners consulted about operation”, and “Full two-way consultation with the community in every step of the planning process”.

Fifth, HF corporations usually have complete control over the economic benefits to the local community, regardless of the growth of HF wells. However, using local companies and services for HF operations is rather common. As O’Connor & Fredericks (2018) noted, in Canada, HF advantages include job creation, promotion of energy independence, tax income for provincial governments, and lower energy prices for consumers. According to Jacquet (2012), compensation may be more important than proximity, particularly if it is offered to the whole community, not just those directly impacted. However, localised monetary incentives may be seen as bribery, hence, the effectiveness of compensation programmes in overcoming community opposition is debatable (Aitken, 2010; Kerr et al., 2017). In this regard, the concept of distributive justice (defined as the equitable allocation of perceived costs and public benefits resulting from HF initiatives) is relevant (Langer et al., 2016). In the wind energy industry, direct cash compensation to neighbouring property owners, proximity-based compensation to property owners, and community payments and/or (infrastructure) investments are among the compensation systems proposed in the literature (García et al., 2016; Lienhoop, 2018; Parkins et al., 2021). This evidence was used by the study to model compensation in terms of distributive justice, such as “No financial benefits for the community”, “Preferential hiring of local services and employers”, “Annual cash grants between $10k and $25k donated to community”, and “Fully funded community project donated to community”.

Finally, induced seismicity is one of the main issues of HF that has been discussed in the literature (Davies et al., 2013; Kim, 2013; O'Connor & Fredericks, 2018). Micro-seismicity, which cannot be felt by humans, is generated by all HF wells (Rubinstein & Mahani, 2015). Between 1985 and 2015, less than 0.3 percent of HF wells in the WCSB were related to M 3.0 earthquakes (possibly felt by humans) (Atkinson et al., 2016). The mere thought of an earthquake, on the other hand, may scare off some people, increasing their opposition to HF operations. HF induced seismicity is noted as the single most important factor influencing support for HF (Lokuge et al., 2023). Seismicity was modelled using a revised form of the Mercalli intensity scale in relation to frequency and its impact as "None-existent", "Too small to be felt", "Persistent and repeating, but too small to cause structural damage", and "Infrequent, but large enough to potentially cause moderate structural damage".

A hydraulic fracturing operation is proposed to be located ***[proximity]*** *from your home. The operation will involve* ***[trucks traffic]*** *with associated noise and dust travelling in the area per day* ***[operational time]****, in addition to traffic already in the area.* ***[Community consultation]*** *during the planning process of the operation. The company involved has a history of policies that involve* ***[benefits]*** *to local communities. Seismicity related to the operation is anticipated to be* ***[seismicity]****.*

Do not support at all					Neutral					Fully support
0	1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○	○

Figure 9: Example of the HF Vignette Scenarios Evaluated

While reading lengthy scenarios (with many attributes) may be tedious, Auspurg & Hinz (2015) suggest that five to nine attributes is a good range, balancing this load with the monotony of reading many similar scenarios (few dimensions). From the six attributes and levels discussed above, there were 1,152 potential combinations of attributes, which is known as a complete factorial design. This refers to the sum of the number of alternatives available for each individual attribute. Each scenario should be assessed numerous times for statistical rigour, indicating that many thousands of respondents are required if the goal is to offer each individual just a few scenarios to evaluate.

The orthogonality of the attribute variables is one of the advantages of employing a complete factorial design. Nothing in the "complete vignette universe" will have any relation to anything else, not even dimensions. There is "level balance" in the vignette universe, which implies that all the levels of each dimension occur at the same rate. However, resources are not unlimited for the implementation of the full vignette universe. Still, it is essential that a significant number of respondents be able to participate in order to ensure that the design is statistically rigorous. The adoption of a fractional design allows for high levels of attribute independence to be maintained while also reducing the number of respondents required.

Using just a random sample from the whole vignette universe, the simplest basic fractional design may be achieved. They are simple to make but may inject bias into the findings and are less exact when estimating parameter coefficients, making them inefficient. By selecting a specified subset of the whole universe, better designs may keep the dimensions and levels nearly orthogonal and balanced while still estimating parameter coefficients with a high degree of accuracy using fewer respondents.

A "foldover design" was utilised in the research, which used an orthogonal fractional factorial design to account for two-way interactions (Auspurg & Hinz, 2015). Systematically altering the dimensional levels in an initial design, foldover designs increase the design's resolution (the degree to which it captures effects and probable interactions between variables) (Ankenman, 1999; Auspurg & Hinz, 2015). Thus, the VE total number of scenarios was whittled down to only 144.

As a first step, the study adopted a design that only tested 72 scenarios, or 1/16th of the original universe. The computer method optimised these 72 scenarios' combinations of dimension levels in order to obtain the most efficient recovery of the whole universe. Finally, the foldover design reduced any attributes that had more than two levels to a two-level equivalent variable. In order to build a foldover design of 72 situations, each two-level equivalent variable was assigned the opposite sign. These additional, opposing 72 scenarios were added to the previous 72 scenarios, for a total of 144. The foldover design aims to ensure that interactions do not obscure the main effects so that any major effects revealed by regressions are genuine effects and not interactions. Six scenarios were chosen at random and shown to each participant.

On a scale of 0 to 10, respondents were asked to rate each scenario they were presented with. Based on this setup, respondents could express their views on a fine enough scale, and the values seemed naturally tied to final judgements such as "do not support at all" and "totally support", making them simple for respondents to comprehend. It is also possible to depict the middle of the spectrum using an eleven-point scale (value of 5).

3.4 Summary of Vignette Ratings

Figure 10 (reproduced from Lokuge et al. 2023)) below shows the vignette rating responses from the survey. With a mean of 4.89 and a standard deviation of 3.80, the figure depicts a rating that is quite balanced. The furious opponents (24.56%) and the lovers (19.44%) of the evaluated scenarios are almost evenly matched, as seen in the figure. Excluding these two extremes, all vignette scenarios have a mean rating of 5.26 and a standard deviation of 2.49.

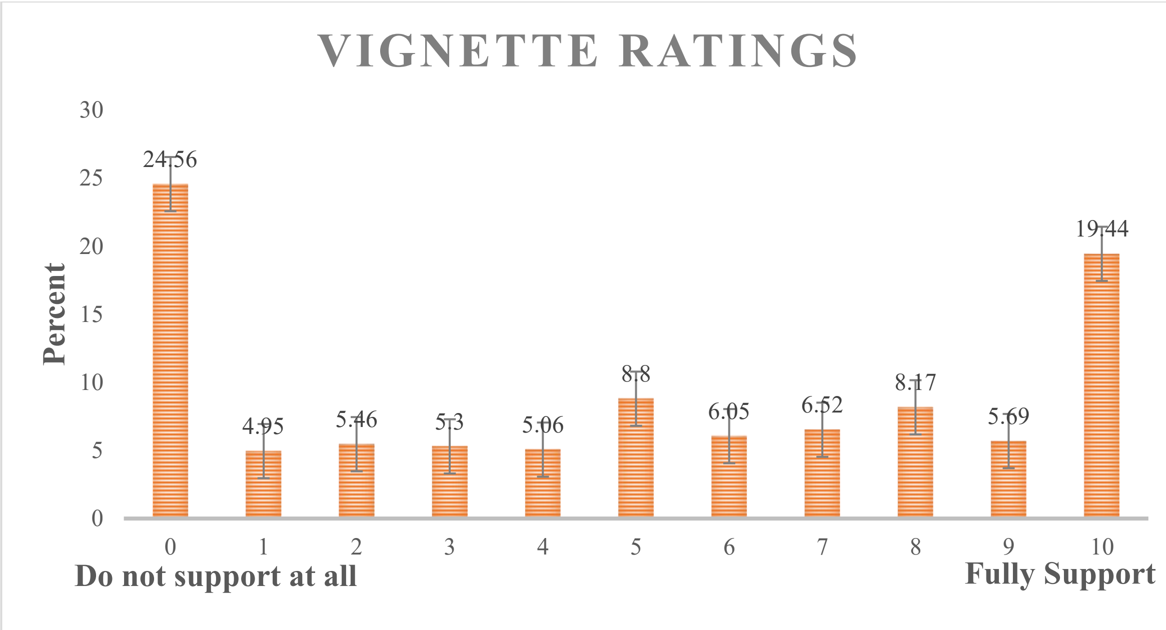


Figure 10: Frequency distribution of VE scenario responses as a percentage of total scenario ratings, n = 7,623

First impressions of the figure suggest a bimodal distribution of outcomes across the vignette scenarios. The degrees of support for the HF scenarios rated, however, become more intricate and balanced if those two extremes are excluded. This indicates that unique project variables mentioned in the vignette scenarios might affect the remaining "average" ratings after the two extremes have been taken into account. This merits more examination of the precise project variables affecting HF endorsement.

3.5 Respondents' Risks, Knowledge, Support, and Acceptability of HF

The public's opinion of HF is affected by a wide variety of factors, including experience in the energy industry, support for renewable and non-renewable energy sources, perceptions of the economic importance of the technology to the national economy, perceptions of the risks and benefits to individuals, general acceptance of HF, etc., as has been shown in other research that links acceptability to induced seismicity (Knoblauch et al., 2019; Lachapelle et al., 2018; McComas et al., 2016; Thomas et al., 2017; Lokuge et al., 2023).

Participants' opinions on whether HF is a suitable method of oil and gas extraction indicate the level of tension in the public sphere around the subject. These opinions are influence by several factors which shape people's perspectives on the technology and help identify the subset to which they belong. From the summary statistics in Table 8 below, about 31.73% of the respondents strongly opposed the idea of HF. What is interesting, however, is that more than half (55.76%) of the respondents strongly agree or somewhat agree that HF is an acceptable way of extracting oil and gas. While only about 44.42% strongly disagree or somewhat disagree with that statement. This illustrates that one third of the population that opposes HF fiercely does so while the majority of the population still accepts it. A significant amount of the population (11.25%) is neutral on the subject. This group has an equal chance of being tipped into either the larger group (HF's lovers) or the smaller group (HF's furious opponents). A national survey conducted by Brunner & Axsen (2020), found that between 40 and 54 percent of respondents supported oil sands and pipeline expansions, while 22 and 34 percent were against them. This suggests that an individual's self-reported support for HF may signal their membership in a certain subset of the population with respect to their views on the technology.

Table 8: Risks, Knowledge, Support and Acceptability of HF

Variable	**Description**	**Sample (n = 1,311) (Percentages)**
HF is an Acceptable way of extracting O&G	Strongly Agree	28.60
	Somewhat Agree	27.16
	Neutral	11.25
	Somewhat Disagree	12.69
	Strongly Disagree	31.73
	Prefer not to say	0.08
Subjective Knowledge of the Energy Industry	Very Knowledgeable	25.72
	Knowledgeable	32.34
	Somewhat Knowledgeable	37.06
	Not Knowledgeable at all	4.38
	Prefer not to say	0.50
Support for Different Energy Sources		
Non-renewable Energy (Oil & Gas, Coal, and Nuclear)	Strongly Support	36.19
	Somewhat Support	21.89
	Neutral	10.61
	Somewhat Oppose	13.16
	Strongly Oppose	18.01
	Prefer not to say	0.14
Renewable Energy (Solar, Wind, and Geothermal)	Strongly Support	50.17
	Somewhat Support	27.10
	Neutral	11.55
	Somewhat Oppose	6.23
	Strongly Oppose	4.86
	Prefer not to say	0.09
Riskiness of HF	Very Safe	24.74
	Somewhat Safe	21.42
	Uncertain	7.85
	Somewhat Risky	27.65
	Very Risky	18.09
	Prefer not to say	0.26
Economic Reliance on Oil & Gas Exploration	Very Safe	22.76
	Somewhat Safe	15.77
	Uncertain	7.59
	Somewhat Risky	25.49
	Very Risky	27.79

	Prefer not to say	0.60
Experience in Energy Industry	Yes	60.79
	No	39.21
Trust in Oil and Gas Industry	Very Untrustworthy	16.59
	Somewhat Untrustworthy	18.78
	Uncertain	9.90
	Somewhat Trustworthy	35.79
	Very Trustworthy	21.11

Subjective knowledge about energy issues and the energy industry in western Canada was also explored in the study, providing essential context for additional investigations. Even though objective knowledge may be preferable in certain circumstances, self-reported knowledge of this kind has been employed before (Stedman, et al., 2016), and this gives a sense of how people's minds are working on this problem or, at the very least, how well acquainted with it they are, in that those who respond "Very Knowledgeable" are likely to have given considerably more thought than those who respond "Not Knowledgeable at all" about the energy industry (Boudet et al., 2016; Kohut et al., 2012; Lachapelle, 2014). According to the statistics in Table 8, approximately 25.75% of respondents stated to be very knowledgeable about the energy industry, while approximately 32.34% stated to be knowledgeable about the subject, and approximately 37.06% stated to be somewhat knowledgeable about the industry. Only a small proportion of 4.38% stated that they were not knowledgeable at all about the energy industry. This high level of self-reported knowledge about the energy industry is consistent with a cross-national survey conducted in Germany and Switzerland (Knoblauch et al., 2019) and the UK, the US, and Canada (Thomas et al., 2017; Pidgeon, et al., 2017). However, Tan et al. (2019) reported low levels of knowledge in China, and McComas et al. (2016) also reported the same findings in the US. The recent increase in media attention to energy systems and debates may have contributed to this high degree of self-reported knowledge. An individual's understanding of the energy sector significantly shapes their perspectives on the risks and benefits associated with HF, consequently determining their categorization within a particular segment.

To successfully address current energy challenges and develop resilient economies, governments throughout the world have been exploring various energy systems. Over the last decade, both renewable and non-renewable energy sources have garnered extensive political attention. This paper looked at the level of public support for both conventional (oil & gas, coal, and nuclear) and alternative (renewable) energy systems (solar, wind, and geothermal). The statistics in Table 8 show that about 50.17% of the respondents strongly support renewable energy sources. 27.10% somewhat support it, while about 11.55% neither support nor oppose it. Only about 6.23% somewhat oppose it, and about 4.86% strongly oppose it. The results also show that about one third (36.19%) of the respondents strongly support non-renewable energy sources and about 21.89% somewhat support them. About 10.61% are neutral on that. However, about 13.16% somewhat oppose it, and about 18.01% strongly oppose it. This high level of support for renewable energy is not unprecedented. In their survey, Brunner & Axsen (2020) showed that when compared to renewable energy and conventional oil, support for oil sands and pipeline projects is lower. In contrast, Parkins et al. (2021) demonstrated in their survey that rural landowners are still not convinced that renewable energy is the future of the economy in their area. Although renewables are becoming more popular, certain studies have shown that natural gas (in and of itself) is still preferable over alternative fossil fuels (Thomas et al., 2017). The varying levels of support for renewable and non-renewable energy sources may play a determining role in the categorization of persons into distinct groups within the population.

The potential hazards of the HF technology also add an intriguing layer to the discussion. Induced seismicity, underground water pollution, economic dependency on oil & gas, GHG emissions, etc., are some of the most prominent dangers cited in the literature (Lokuge et al., 2023). Questions on the perceived dangers of the HF technology were posed to respondents. Table 8 shows that about 46.16% of the respondents felt that HF was very safe (24.74%) or somewhat safe (21.42%), while about 45.74% viewed it as being very risky (18.09%) or somewhat risky (27.65%). About 7.85%, however, are uncertain about the riskiness of HF. This shows that opinions are evenly divided on whether HF activities are dangerous or safe. Previous research has shown that one's level of experience may either heighten or decrease one's sensitivity to risk, confirming the theory of social amplification of risk (Gunzburger et al., 2017; Kasperson et al., 1988; Renn et al., 1992; Thomas et al., 2017; Willits et al., 2016). Brunner & Axsen (2020) reported that Albertans are far less likely to report a high level of concern about threats to their health and the environment regarding HF activities. Considering studies indicating that physical distance might affect people's willingness to take risks, Knoblauch et al. (2019) found that lower perceptions of seismic risk in rural regions led to higher acceptance rates than in metropolitan areas. The classification of individuals within the population is likely to be influenced by their subjective evaluations of the risks and benefits associated with HF.

Acceptance of energy technology is also affected by one's familiarity with and use of that technology (Huijts et al., 2012), but there are conflicting results on whether increased familiarity with HF increases support for the technology (Brunner & Axsen, 2020). The statistics in Table 8 above indicate that about 60.79% of the respondents in the survey have energy-related work experience, while the remaining 39.21% do not have any experience in the energy industry. This high number of people with energy-related work experience is not surprising, as the western provinces of Canada are famous for their rich-energy industries. Those with work-related experience in the energy industry may have profited in some way from HF's activities. However, this raises the possibility that they were exposed to HF dangers on a large scale. The way individuals see HF and, by extension, the groups they identify with, will likely be affected by these interconnections.

Energy technologies may become contentious if individuals stop trusting the people in charge (Knoblauch et al., 2019). Data on respondents trust in the oil & gas industry shows that about 21.11% of them perceive the industry to be very trustworthy, while about 35.79% perceive the industry to be somewhat trustworthy. However, 16.59% of the respondents perceive the industry to be very untrustworthy, and 18.78% perceive it to be somewhat untrustworthy. This implies that the majority of the respondents have confidence in the oil & gas industry. There may be subgroups within the population that are defined by their support (or lack thereof) for HF operations based on their level of trust in the oil and gas industry.

After discussing the techniques of the survey design, the representativeness of the sample, as well as the summary statistics of relevant survey variables, the subsequent sections are structured as follows: Section 3.6 presents the econometric model specification of the focus of this paper (the latent class model). Section 3.7 discusses the model estimation techniques, the analysis flowchart, the selection of the optimal number of classes, and the estimation software.

3.6 Specification of the LCM

LCA is used to model people's preferences regarding HF. Specifically, it is as described below: an individual (i) receives an indirect utility (U) from rating (relative to other vignette scenarios) a vignette scenario (q) equal to $U_{iq} = U(Q_{iq})$, where Q_{iq} is a vector of the attributes of q. In this framework, utility is split into a deterministic part that is dependent on the characteristics of the vignette scenarios and an a-deterministic part that is independent of those characteristics. Thus,

$U_{iq} = V_{iq} + \varepsilon_{iq}$ where $V_{iq} = f(Q_{iq})$ is the deterministic part and ε_{iq} is the error component of the utility framework. In this model, individual i rates a vignette scenario from a finite set C of scenarios.

The probability (P) that scenario q is rated high (preferred) is equal to the probability that the utility gained from rating this scenario high (preferred) is greater than or equal to the utilities of rating other scenarios in C. The probability of rating scenario q high is;

$$P_i(q) = Prob\{V_{iq} + \varepsilon_{iq} \geq V_{ik} + \varepsilon_{ik}; q \neq k, \forall k \in C\} \quad (1)$$

If the random components are considered to be independently distributed Type-I extreme value variates, the conditional logit model introduced by McFadden & Zarembka, 1974, can be used to estimate these probabilities. To do this, it is assumed that the data is in a standard rectangular file format, in which there are multiple responses for each individual i. The T_i response variable or indicators – which are denoted by y_{it} – appear in T columns, $1 \leq t \leq T_i$.

Exogenous variables, called covariates, are denoted as $z_{ir}^{cov}, 1 \leq r \leq R$, where R is the number of covariates. In addition to covariates, exogenous indicators that may change across classes are included in the regression model to better predict the outcome of the repeated measurement of the vignette ratings. These predictors or attributes are denoted by $z_{itq}^{pred}, 1 \leq q \leq Q$, where Q is the number of vignette attributes.

Finally, it is assumed that there is a nominal latent variable x with K classes, $1 \leq x \leq K$. The general model probability structure that defines the relationship between the exogenous, latent, and the rating variables is;

$$f(y_i|z_i) = \sum_{x=1}^{K} P(x|\, z_i) f(y_i|x, z_i) = \sum_{x=1}^{K} P(x|\, z_i) \prod_{t=1}^{T} f(y_{it}|\, x, z_i) \quad (2)$$

Where y_{it} denote one of the T subsets of y_{it}. The last part of the model implies that the ratings variable y belonging to different sets are assumed to be mutually independent given the latent exogenous variables:

$$f(y_i|x, z_i) = \prod_{t=1}^{T} f(y_{it}|\, x, z_i) \tag{3}$$

Including both predictors and covariates into the model, the probability of giving a particular vignette rating is define as:

$$f(y_i|z_i) = \sum_{x=1}^{K} P(x|\, z_i^{cov}) f\left(y_i|x, z_{it}^{pred}\right) = \sum_{x=1}^{K} P(x|\, z_i^{cov}) \prod_{t=1}^{T_i} f(y_{it}|\, x, z_{it}^{pred}) \tag{4}$$

Giving that the rating variable is ordinal, it is assumed to come from a multinomial distribution with M_t entry, where, $1 \leq m \leq M_t$. The adjacent-category ordinal logistic regression model with the ordinal rating variable has a distribution:

$$P(y_{it} = m|x, z_i) = \pi_{m|t,x,z_i} = \frac{\exp\,(\eta_{m|x,z_i}^{t})}{\sum_{m'=1} \exp\,(\eta_{m'|x,z_i}^{t})} \tag{5}$$

Here, $\pi_{m|t,x,z_i}$ is the probability of giving rating m given x and z_i. $\eta_{m|x,z_i}^{t}$ denotes the linear term that is restricted by the regression model to yield a multivariate logistic model.

$$\eta_{m|x,z_i}^{t} = \beta_{m0}^{t} + \beta_{x0}^{t} \cdot y_{m_t}^{t*} + \sum_{r=1}^{R} \beta_r^{t} \cdot y_{m_t}^{t*} \cdot z_{ir}^{cov} \tag{6}$$

Where $y_{m_t}^{t*}$ is the rating assigned to category m_t of the tth indicator.

Estimation of the parameters is done via maximum likelihood, which estimates the LC ordinal logit model with random effects. The econometric model estimated is specified as;

$$log\left[\frac{P(Y_{it}=m|x)}{P(Y_{it}=m-1|x)}\right] = a_{im} + \sum_{q=1}^{6} \beta_{xq} z_{tq} \tag{7}$$

Evidently, this is a regression model for the logit associated with giving a rating m instead of $m-1$ for vignette scenario q conditional on membership of latent class x, for $x = 1,2,\ldots,K$. With this specification, a_{im} is the intercept, which is allowed to vary across individuals. The parameterization used is $a_{im} = a_m + \lambda F_i$, where F_i is normally distributed continuous factor (C-Factor score for the ith individual), which has a mean zero and variance 1, and λ is a factor loading (Goldstein, 2007; Magidson & Vermunt, 2007; McFadden & Train, 2000; Skrondal & Rabe-Hesketh, 2004; Vermunt, 1994, 2014; Vermunt & Magidson, 2016; Weller et al., 2020). Equation 7 above becomes;

$$log\left[\frac{P(Y_{it}=m|x)}{P(Y_{it}=m-1|x)}\right] = a_m + \lambda F_i + \sum_{q=1}^{6} \beta_{xq} z_{tq} \qquad (8)$$

Where z_{tq} denotes the value for attribute t for vignette scenario q, and β_{xq} is the effect of the t^{th} attribute (and other respondent variables/socio-demographics) for the latent class x.

3.7 Estimation Techniques

The research assumes that people's preferences for HF activities are influenced by a variety of underlying characteristics. Individuals' preference heterogeneity enables them to be grouped into classes (LCM), with marginal utility characteristics that change depending on their class membership (Boyle, 2017; Greene & Hensher, 2003; Scarpa et al., 2009). Random Parameters Logit (RPL) and the LCM can be used for such analysis in the sense that they allow for preference heterogeneity and remove the Independence of Irrelevant Alternatives assumption. Whereas the LCM assumes a limited mixture of preferences, the RPL posits that the utility of choice is continuously variable (Hess & Train, 2017). As a result, the LCM is used in this work since it not only allows for preference heterogeneity but also provides a more parsimonious method of modelling preference heterogeneity (Johnston et al., 2017). In addition, since the goal is to identify any patterns in people's preferences for HF operations, categorising them into distinct groups might give more useful and comprehensible information for policymakers. Based on respondents' stated preferences over attribute values and socio-demographic variables, the LCM model classifies them into subgroups.

The ideal number of classes was determined as follows: A combination of the Bayesian Information Criterion (BIC), the Akaike Information Criterion (AIC), entropy, theoretical interpretation, and the log-likelihood (LL) model performance statistics were used since there is no specific statistical test to help guide the selection of the number of classes (Khan et al., 2021; McCutcheon, 2011; Nylund et al., 2007; Weller et al., 2020).

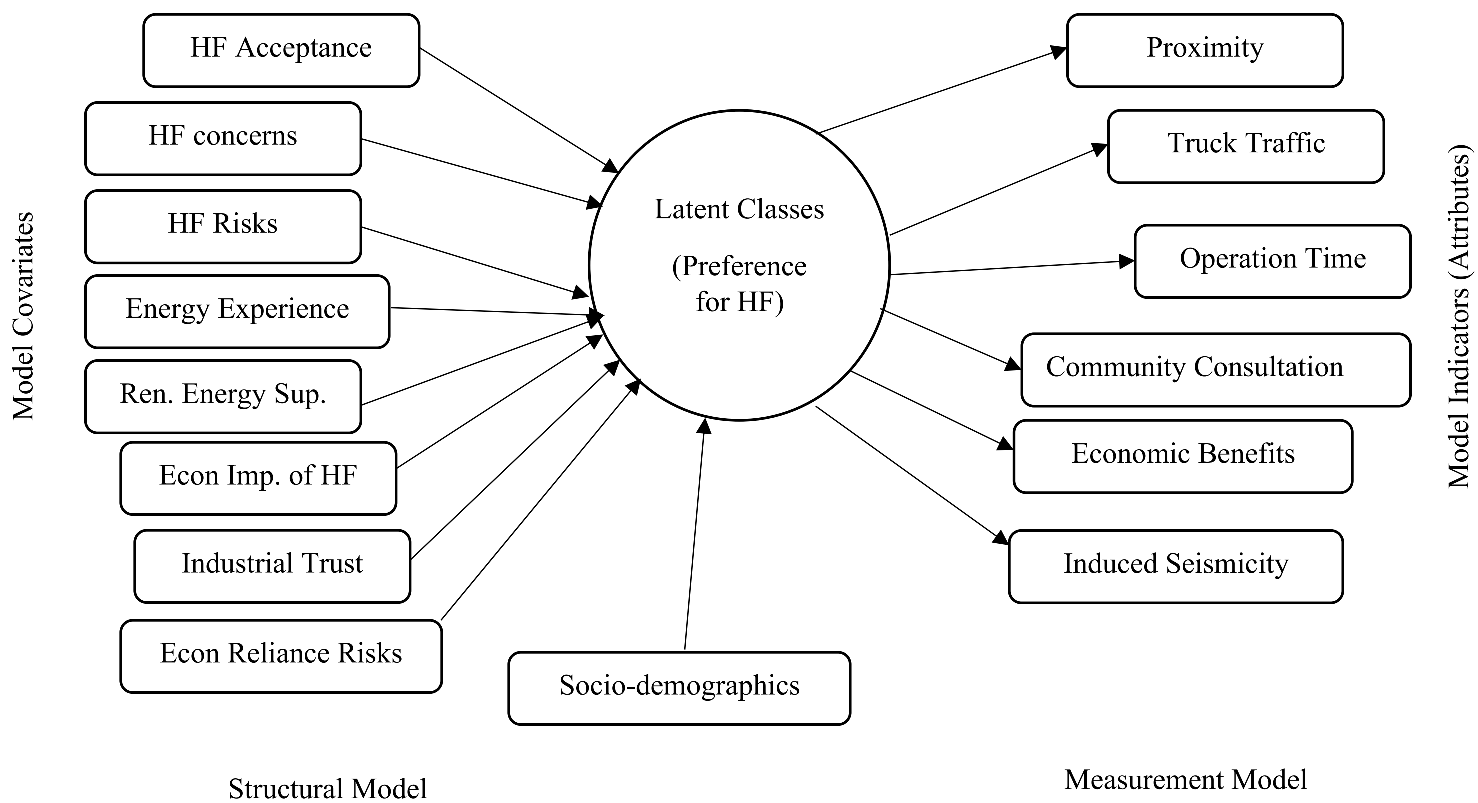


Figure 11: Path diagram of the complete LCM of public perceptions of HF

One to seven classes of models with the same specification were estimated in the analysis. An ordered logit random intercept LCM was estimated by using Latent GOLD 6.0, assuming that individuals with identical underlying characteristics are placed in the same subgroups. Respondents' socio-demographic variables and energy-related survey variations were added to the base model as active covariates. LC solutions with active covariates may differ somewhat from those without active covariates because "active" covariates not only define the structural model but also has effects on the measurement model (as shown in Figure 11 above) (Vermunt et al., 2016). Figure 11 above shows a path diagram of the complete LCM. Four socio-demographic variables (age, gender, education, and place of residence) as well as eight energy-related survey variables (HF acceptance, HF concerns, HF risks, energy experience, support for renewable energy, trust in oil and gas industry, economic reliance risks, and perceptions of the economic importance of HF) were also used as covariates (or class defining variables).

4.0 Results

At both the exploratory and confirmatory stages of the analysis, the fit of an LC-ordered logit model with random effects for 1–7 classes was checked using only the vignette attributes as independent variables (measurement model only). As there is no agreement on what fit statistics should be used when selecting a final model, the BIC, AIC, entropy, and theoretical interpretability were referred to (Nylund et al., 2007; Nylund-Gibson et al., 2022; Weller et al., 2020).

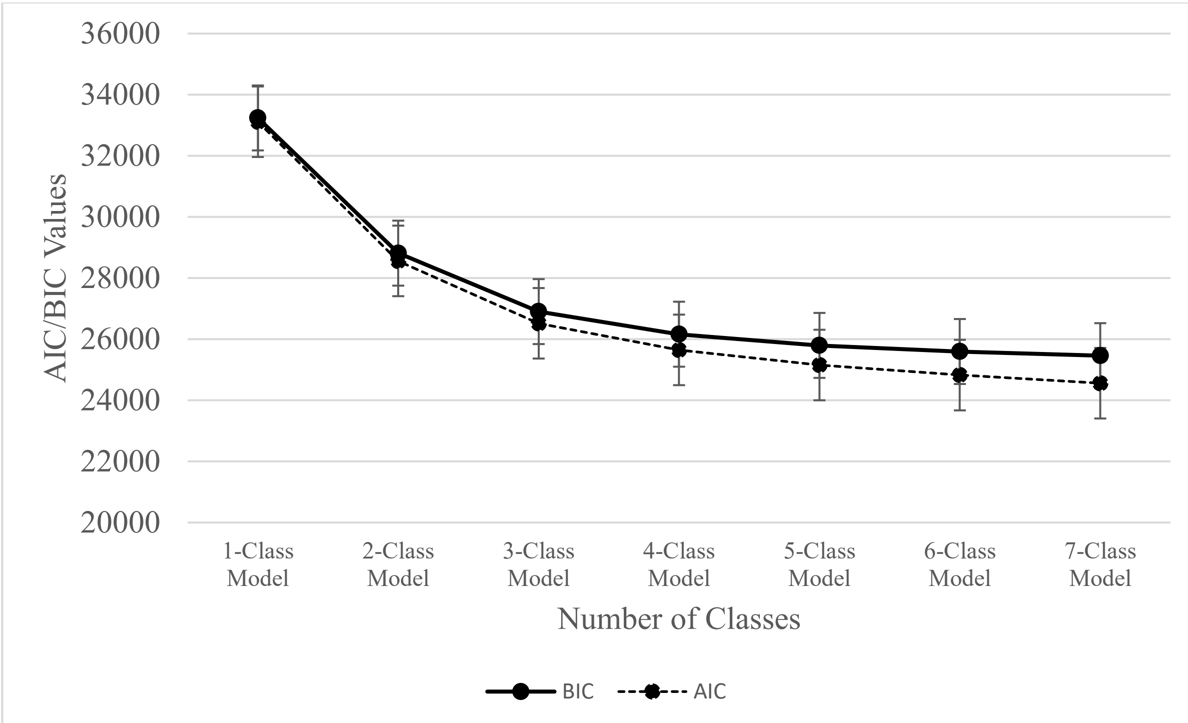


Figure 12: Optimal Number of Classes Using the AIC/BIC Criteria

The models and their respective fit statistics are shown in Table 9. Overall, the observed statistics, interpretability, and distinction between classes all favour the four-class model as the best fit. The BIC values continue to drop for more sophisticated solutions, but the narrowing gap between models with more than four classes indicates the presence of an elbow point (Figure 12), and hence, a good enough fit for the 4-class model. With LCMs, Muthén (2004) suggests entropy values greater than 0.7, as greater entropy indicates more clearly differentiated classes. The four-class model has an entropy of 0.91, which signifies a sufficient distinction between the classes. The subsequent analyses were based on the four-class model identified.

Table 9: LC models and fit indices

No. of Classes	LL	BIC(LL)	AIC(LL)	L^2	df	p-value	VLMR	Entropy	R^2
1-Class Model	-16533.3	33238.8756	33114.5905	33063.8179	1287	0.000		1	0.0736
2-Class Model	-14231.4	28814.5052	28560.7565	28459.9839	1262	0.000	4603.8341	0.9232	0.6789
3-Class Model	-13185.7	26902.6445	26519.4321	26368.6595	1237	0.000	2091.3244	0.917	0.7608
4-Class Model	**-12725.7**	**26162.0584**	**25649.3824**	**25448.6098**	**1212**	**0.000**	**920.0497**	**0.9077**	**0.7839**
5-Class Model	-12453	25796.1247	25153.985	24903.2124	1187	0.000	545.3973	0.8942	0.8011
6-Class Model	-12263.2	25596.0208	24824.4175	24523.6449	1162	0.000	379.5675	0.8914	0.8057
7-Class Model	-12105.7	25460.5232	24559.4563	24208.6837	1137	0.000	314.9613	0.8906	0.8111

Note: LL=Log-likelihood, BIC=Bayesian information criterion, AIC=Akaike's information criterion, L^2=likelihood ratio df=degrees freedom, VLMR=Vuong-Lo-Mendell-Rubin likelihood ratio. Bold indicates the selected model.

4.1 Class Properties and Mean Vignette Ratings

The results obtained from the estimation of the LCMs indicate the presence of four statistically distinct classes or groups of respondents, characterised by their indicated support (ratings) for hypothetical HF projects. From Table 10, the three different specifications (attributes only model – model 1, attributes with socio-demographics as covariates - model 2, and attributes with survey variables as covariates – model 3) of the four-class model show that the LCs accurately predicted the respondents' class memberships with an entropy of 91% and 92%. The entropies of the models demonstrate robustness, as they exhibit significantly distinct and consistent mean ratings of HF vignette scenarios.

Table 10: Posterior mean ratings and class sizes

	Class 1		Class 2		Class 3		Class 4		Entropy
	Mean	Size	Mean	Size	Mean	Size	Mean	Size	
Model 1	3.82	28.28%	0.50	25.13%	8.77	24.19%	7.06	22.40%	0.91
Model 2	3.80	28.02%	0.50	25.03%	8.75	24.30%	7.05	22.65%	0.91
Model 3	3.81	29.23%	0.47	24.61%	8.75	24.22%	7.10	21.94%	0.92

The different classes were assigned traffic-light-style labels based on their distinct average support ratings of vignette scenarios across classes. The colour "green" was given to Class 3, which had the highest mean rating (8.76 out of 10) and accounted for 24.24% of the respondents. Class 4, described as "yellow," has the second highest mean rating with an average rating of 7.07 and accounts for 22.33% of the respondents. Class 1 labelled "orange," contains 28.51% of the respondents with a mean rating of 3.81. Class 2, classified as "red," carries the lowest average rating of 0.49 and is represented by 24.92% of the total respondents. The classes exhibit significant variations in their average support ratings of proposed HF development scenarios in western Canada. This necessitates conducting an LCA to investigate the causes of these differences. The attributes of the HF scenarios, respondents' socio-demographic variables, and other energy-related survey variables are used as predictors and class-defining variables to investigate this.

4.2 Results of LCM with only Vignette Attributes

Table 11 below shows the results of the LC base model (attributes only model). The Wald (=) statistic indicates that the differences in the vignette attributes across the four classes are statistically significant at 5% except for the attribute truck traffic and seismicity. This suggests that the four groups have distinct sensitivities to certain project attribute levels. Figure 13 below shows the sensitivity of the various classes to the different vignette attributes (which attributes matter most to which class). While Table 11 highlights the magnitude and signs of the attribute levels (the likelihood of giving a particular vignette rating or direction of rating). We therefore refer to both Figure 13 and Table 11 concurrently to provide insights and interpretations in the discussion.

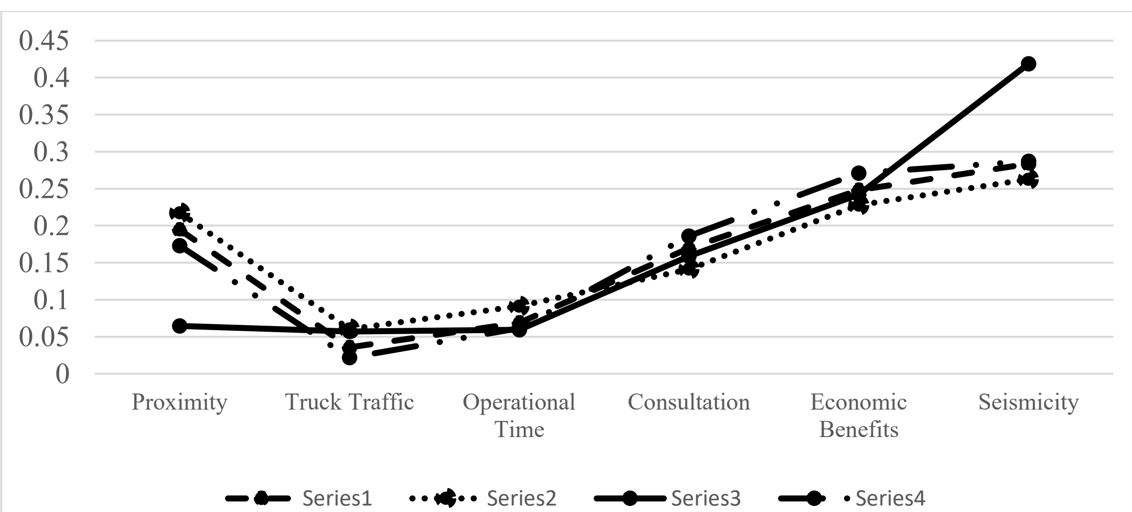


Figure 13: Vignette attributes importance plot

Table 11: Results of LCM with vignette attributes as predictors (base model)

Attributes	Orange (Class 1)	Red (Class 2)	Green (Class 3)	Yellow (Class 4)	Wald (=)	p-value
Proximity						
less than 3 km	-0.1754***	-0.1962***	-0.0214*	-0.1568***	61.8959	0.000
between 3 and 15 km	-0.0075	-0.0415	-0.0164	0.0031		
over 15 km	0.1829***	0.2376***	0.0377**	0.1537***		
Truck Traffic						
up to 10	0.037**	0.0298	0.0291**	0.024	6.4654	0.37
10-50	-0.0083	-0.0751**	-0.0059	-0.0149		
over 50	-0.0286**	0.0453*	-0.0232*	-0.0091		
Operation Time						
between 8 am and 8 pm	0.0635***	0.0911***	0.0272**	0.0553***	8.1111	0.044
at all hours of the day	-0.0635***	-0.0911***	-0.0272**	-0.0553***		
Community Consultation						
community not informed of plans	-0.1938***	-0.1751***	-0.0911***	-0.223***	21.6896	0.0099
community informed of plans	0.028*	0.0398	0.0213	0.0675**		
directly affected landowners consulted during planning	0.0475**	0.0289	0.0154	0.0446*		
full two-way consultation	0.1183***	0.1064***	0.0544**	0.1109***		
Economic Benefits						
no financial benefits	-0.2764***	-0.2406***	-0.1507***	-0.3253***	43.2535	0.000
preferential use of local services and employees	0.0817***	0.0361	0.0411**	0.1404***		
donating community grants ranging from $10k to $25k annually	0.0143	-0.0094	0.0379**	0.024		
donating fully funded community projects	0.1803***	0.2139***	0.0716***	0.1609***		
Seismicity						
None-existent	0.2001***	0.2027***	0.1181***	0.1656***	14.0591	0.12
too small to be felt	0.1437***	0.1755***	0.1296***	0.1703***		
persistent and repeating, but too small to cause structural	-0.0216	-0.0567	0.0069	0.0091		
infrequent, but large enough to potentially cause moderate damages	-0.3222***	-0.3215***	-0.2546***	-0.345***		
Intercept	0.127**	0.0087	-0.0295	-0.1061**	6.7327	0.081

*p-value ≤ 0.1, ** p-value ≤ 0.05 and *** p-value ≤ 0.01

Economic benefits, which raise issues of fairness and are intimately related to distributive justice, are an important factor in determining whether or not new energy technologies are accepted (Parkins et al., 2021). Figure 13 above shows that class 4 (the yellow class) places so much importance on the economic benefits of HF as compared to the other three segments of the population. The results in Table 11 above show that an HF project with no financial benefits to the local community within which it operates negatively affects HF project support across all four segments of the population. The class 4 (yellow) and class 2 are the most sensitive to this level of the economic benefits attribute. When an HF project gives preference to local services and workers, it gains support from class 3 (green), 4 (yellow), and 1 (orange) segments of the population but has no effect on class 2 (red). However, donating community grants ranging from $10k to $25k annually and/or donating fully funded community projects, will garner more support across all four classes, with class 2 (the red class) giving relatively the highest support. This result may be explained by the work of Tan et al. (2019), who observed that individuals who receive little or no financial benefits turn to perceive higher risks from HF. Brunner & Axsen (2020) noted significantly higher perceptions of economic benefits among respondents in Alberta. Our findings, however, suggest that the class 3 (green) and the class 4 (yellow) constitute less than half (46.57%) of the respondents. While there is debate in academic literature regarding the ethical implications of providing direct financial compensation to individuals impacted by a project (Aitken, 2010; Kerr et al., 2017), our findings indicate that the implementation of well-designed community projects and other forms of community benefits, as part of a company's corporate and social responsibilities, are crucial for garnering local community support and acceptance.

Regarding the perceptions of induced seismicity by HF, there is an interesting dynamic across the four segments of the population. As shown in Figure 13 above, class 3 (the green class) is the most sensitive to the induced seismicity attribute, while class 2 (the red class) is the least sensitive. Even though there is a negative correlation between HF rating and induced seismicity, the people who worry the most about this issue are the ones who adore HF the most. From Table 11 above, an HF project with no possibility of induced seismicity has a positive effect on the project rating across all segments of the population. A project that has the possibility of causing seismicity that is too small to be felt on the surface of the earth is still acceptable to all four segments of the population. What is intriguing, however, is that the red class (class 2) and the yellow class (class 4) find it more acceptable than the green class (class 3) and the orange class (class 1). Induced seismicity that is infrequent but large enough to potentially cause moderate damages has a negative impact on the HF rating across all four classes, with the class 4 (yellow) and class 1 (orange) being more sensitive than the class 3 (green) and class 2 (red) segments of the population. This confirms the findings of Knoblauch et al. (2019) and McComas et al. 2016 who found more negative reactions to induced seismicity related to energy development than earthquakes caused by natural causes. An analysis by Lokuge et al. (2023) noted that despite the clear polarisation around HF (and fossil energy in general) among respondents, the fear of HF-induced earthquakes, which grows at the suggestion of any damages, no matter how improbable they might be, is a major unifying factor standing in the way of HF acceptance in western Canada. Our result reveals that avoiding and/or managing the risks of induced seismicity is paramount for individuals across all segments of the population.

The community engagement and consultation attribute highlight the distinction between the four segments of the population in their preferences for HF. While all four classes value consulting their local communities and relevant stakeholders, there is a difference in the magnitude of their sensitivities. From Figure 13 above, we observe that class 4 (yellow) is highly sensitive to this attribute as compared to the other three classes. From Table 11 above we observe that all four segments are severely affected by HF's lack of communication on its goals and activities, although class 4 (yellow) and class 1 (orange) are the most vocal in their opposition. Informing the local community about the HF project plan and directly consulting affected landowners increases the HF rating for those in class 1 (orange) and class 4 (yellow). The class 3 (green) and class 2 (red), however, are not affected by these two levels of engagement. Similarly, a full two-way consultation positively impacts HF rating across the four classes, but the class 4 (yellow) and class 1 (orange) are more attuned to this kind of community involvement. These results confirm the findings of Lienhoop (2018) and Parkins et al. (2021) who found a positive relationship between effective community engagement and the acceptance of energy technologies. This suggest that actively involving local community members and establishing a full two-way consultation as an integral part of the planning and implementation process for an HF project is essential to ensuring public support for that project.

From Table 11, with the proximity attribute, it is observed that all four classes have a negative reaction if an HF project is less than 3 km from their place of residence. However, the class 1 (orange) and class 2 (red) are more sensitive to this attribute as compared to class 3 (green) and class 4 (yellow). All four classes, however, are passive when the HF project is between 3 and 15 km from their place of residence. But we observe a positive HF project scenario rating across all four classes if the HF project is more than 15 kilometres from residential areas. It is also worth noting that class 2 (red) has the highest probability of giving a positive rating when the HF project is situated at a distance more than 15 km from the individual's residence. This attribute is related to the NIMBYism phenomenon, which is extensively discussed in the energy and environmental management literature. Yet insights from the published literature are nuanced and multifaceted.

While Liebe & Dobers (2019) found a negative association between NIMBY beliefs and the acceptance of wind power and biogas plants, Parkins et al. (2021), on the other hand, observed a positive relationship between location and acceptance of wind power plants. In their research, McLaughlin & Cutts (2018) noted that whereas few object to drilling in remote areas, public opinion favours keeping HF in places already zoned to prevent unnecessary risks. Our results suggest that an HF project of over 15 km away from residential areas may be sufficient to positively influence public support for HF activities in their localities.

The attribute "operational time" within normal working hours (8 a.m. to 8 p.m.) has a positive effect on HF rating (Table 11) across all four segments of the populations, only varying in sensitivity (Figure 13 above). However, operating during all hours of the day (day and night) negatively impacts the HF project's rating across all four segments of the population (holding all other variables constant). In terms of magnitude, the class 2 (red) and class 1 (orange) are highly sensitive to operational hours as compared to class 3 (green) and class 4 (yellow), with class 1 (orange) being on top of the list. A recent report by Mccleary & Coupe (2022) asserts that residents near HF sites complain that activities at those sites keep them up at night. This discomfort may explain why all four segments of the population respond negatively to daytime and night-time HF operations.

Finally, truck traffic in the local community in which the HF project operates is statistically significant in explaining the HF project scenario rating but there is no statistically significant difference across the four segments of the population. Figure 13 above illustrates that class 2 (the red) is the most sensitive to this attribute. Specifically, from Table 11 above, an HF project with up to ten trucks has a positive effect on the project rating across the class 3 (green) and class 1 (orange) segments of the population. The class 2 (red) segment of the population has less support for HF when there are ten to fifty trucks on the road. But it is only after the number of trucks increases to over fifty that the class 3 (green) and class 1 (orange) become less supportive of HF. The yellow class (class 4), however, is not sensitive to any level of the truck traffic attribute. The local effects of HF, such as traffic and noise, are often given little consideration (Thomas et al., 2017), which may explain why there is no distinction across the four classes in their sensitivity to truck traffic. However, a decreased support as a result of the increased number of trucks on the road were reported by Anderson & Theodori (2009) and Wynveen (2011), that individuals living near HF sites usually express worry about high rate of traffic accidents. According to Holeczek, (2019) and O'Connor & Fredericks, (2018), other variables that contribute to the negative perceptions of HF include noise and dust pollution resulting from truck traffic, as well as potential damage to local road infrastructure. The findings of our study suggest that the implementation of measures aimed at decreasing and streamlining the number of trucks involved in an HF project is likely to enhance the level of endorsement for such project.

The current analysis provides valuable insights into the varying class profiles in relation to their support for HF and their evaluations of HF-induced seismicity risks, as well as other project attributes that hold significant importance to them. However, for the purpose of informing policy decisions, it would be beneficial to gain a comprehensive understanding of the individuals comprising each segment of the population and their respective perceptions of HF. As a result, we extend the analysis to include the socio-demographic characteristics of respondents and other survey factors as determinants of classes.

4.3 LC Memberships Based on Socio-demographics and Survey Variables

Respondents' socio-demographic variables and energy-related survey variables were added to the attributes only model (base model) as class determining variables (covariates). The results from these two models (Appendix: Table 16 and Table 17) indicate that there is no statistically significant variation in the attributes coefficients from the outcomes of the base model. This suggests that the LC solutions are robust. The Wald (=) statistics indicate that all six attributes, except truck traffic, are statistically significantly different across the four segments of the populations. All the covariates included in the model are statistically significant in predicting individuals class memberships and are also significantly different across all four classes (except economic reliance risks). Since the coefficients for the covariates in those models are likelihood ratios, we turn to Table 12 to discuss their marginal effects.

Table 12: LC Membership Base on Socio-demographics and Survey Variables

Dep. variable: class memberships	*Marginal Effects (probabilities)*							
Covariates	*Class 1*	*SE*	*Class 2*	*SE*	*Class 3*	*SE*	*Class 4*	*SE*
Attributes + socio-demographics								
Age	-0.0146	0.00982	-0.0079	0.0094	-0.0023	0.00913	0.0248***	0.00899
Gender	-0.0628**	0.02944	-0.1338***	0.02763	0.1653***	0.02864	0.0313	0.02797
Urban	0.0854***	0.03054	-0.0107	0.02853	-0.0803***	0.02795	0.0055	0.02809
Post Sec.	-0.0321	0.04497	0.0924**	0.03633	-0.0677	0.04373	0.0074	0.04089
Attributes + survey variables								
Energy experience	-0.1090***	0.0413	-0.0296	0.02072	0.0514***	0.01778	0.0873**	0.03937
HF Concerns	0.0126***	0.00299	0.0058***	0.00143	-0.0097***	0.0017	-0.0087***	0.00285
HF Acceptance	-0.07548***	0.02248	-0.0628***	0.01268	0.0477***	0.00995	0.0905***	0.0214
HF Risk	0.0466**	0.02116	0.0639***	0.01214	-0.0512***	0.01027	-0.0593***	0.01959
Renewable Energy Support of HF	0.0411***	0.01429	-0.0016	0.00828	-0.0075	0.00493	-0.0320**	0.01263
Economic Importance	-0.0375**	0.01851	-0.0277***	0.00842	0.0154*	0.00824	0.0450***	0.01826
Industrial Trust	-0.0051	-0.01135	-0.0287***	0.00612	0.0131***	0.00495	0.0207*	0.01062
Economic Reliance Risks on HF	0.0162	0.01619	0.0059	0.00913	-0.0085	0.00641	-0.0136	0.01487
Number of obs	*1,133*							
LR chi2(24)	*1159.06*							
Prob > chi2	*0.0000*							
Log likelihood	*-988.00332*							
Pseudo R2	*0.3697*							

SE = Standard errors, *p-value ≤ 0.1, ** p-value ≤ 0.05 and *** p-value ≤ 0.01

The results in Table 12 show that gender plays a vital role in individuals' perceptions of HF. The results show that male respondents are 16.53% more likely to be in class 3 (green) and 13.38% less likely to be in class 2 (red) as compared to their female counterparts. Also, male respondents are 6.28% less likely to be in class 1 (orange) as compared to their female counterparts. 71.11% of those in class 3 (green) are males, while 57.82% of those in class 2 (red) are females (Appendix: Table 15). The predominance of men in the western Canadian energy workforce may potentially explain their overwhelming representation in class 3 (green). A similar line of research by Jacquet (2012) also noted that females have negative reactions towards natural gas drilling. Mooney et al. (2022) and Truong et al. (2019) also noted that females have less support for HF as compared to men. Our results suggest that endeavours aimed towards enhancing support for HF (as well as non-renewable energy sources) should prioritise the female demographic, while initiatives aimed at bolstering support for renewable energy (clean energy sources) should focus on engaging the male demographic.

The findings in Table 12 above demonstrate that a person's likelihood of being in class 4 (the yellow class) rises by 2.48% for every decade of life. 69.1% (Appendix: Table 15) of the individuals in this class are between the ages of 35 and 75 years. This finding is consistent with Gunzburger et al.'s (2017) observation that people between the ages of 46 and 80 are more likely to prefer the health and economic benefits of unconventional gas extraction.

The results in Table 12 above also show individual's level of education is negatively associated with support for HF. Specifically, respondents with post-secondary education or higher are 9.24% more likely to be in class 2 (red). 91.58% of those in the red class have post-secondary education. Studies by Boudet et al. (2014) and Jacquet, (2012) also found negative relationships between level of education and support for HF. This suggests that those with higher levels of education may be more aware of environmental issues and hence less inclined to support actions that might have negative consequences for the environment.

Finally, an individual's place of residence is also associated with support for HF. The results in Table 12 above reveal that individuals living in urban areas are 8.03% less likely to be in class 3 (HF lovers) and 8.54% more likely to be in class 1 (orange) as compared to individuals living in rural areas. 65.10% of those in class 1 (orange) live in urban areas, while 48.08% of those in class 3 (green) live in rural areas (Appendix: Table 15). This does not come as a surprise, as most HF activities are closer to rural areas than urban areas. As a result, residents in those areas are more likely to benefit economically from HF activities, such as compensation and employment, justifying their support for HF. Similarly, Knoblauch et al. (2019) noted that those in rural areas have lower perceptions of HF-induced seismic risks and by extension high support for HF (Lokuge et al., 2023).

Regarding the energy-related survey variables, the results in Table 12 indicate that individuals with high experience in the energy industry are more likely to be in class 3 (green) and class 4 (yellow) but less likely to be in class 1 (orange class). Specifically, an increase in experience in the energy industry increases the probability of being in class 3 (green) by 5.14% and class 4 (yellow) by 8.73%. However, an increase in energy experience decreases the probability of being in class 1 (the orange) by 10.9%. This implies that experience in the energy industry is positively correlated with being in class 3 (green) or a member of class 1 (orange). Huijts et al. (2012) noted a positive relationship between working in the oil and gas industry and support for HF. Brunner & Axsen, (2020), however, observed conflicting results. Our results suggest that the impact of energy-related work experience on support for HF varies depending on the specific segment of the population a person belongs.

Respondents who regard HF as an acceptable means of oil and gas extraction are more likely to be in class 3 (green) and class 4 (yellow) but less likely to be in class 1 (orange) and class 2 (red). Specifically, an increase in an individual's perception of the acceptability of HF as a means of oil and gas extraction increases their likelihood of being in class 3 (green) by 4.77% and in class 4 (yellow) by 9.05%. However, an increase in HF acceptance decreases the probability of being in class 1 (orange) by 7.55% and class 2 (red) by 6.28%. Similarly, respondents who expressed high concerns about the negative impacts of HF are more likely to be in class 2 (red) and class 1 (orange) but less likely to be in class 3 (green) and class 4 (yellow). An increase in an individual's concern about HF decreases their probability of being in the green class (class 3) by 0.97% and in the yellow class (class 4) by 0.87%. However, increases in concern increase the likelihood of being in the orange class (class 1) by 1.26% and in the red class (class 2) by 0.58%. Observations in the literature (Drummond & Grubert, 2017; Evensen et al., 2022; Lokuge et al., 2023) may be explained, at least in part, by the fact that people of different socioeconomic backgrounds have different degrees of worry about HF and hence different levels of support for it.

Furthermore, individuals who perceive HF as a very risky venture are more likely to be in class 2 (red) and class 1 (orange) segments of the population but less likely to be in class 3 (green) and class 1 (yellow). Specifically, an increase in an individual's risk perceptions of HF increases the probability of being in the red class (class 2) by 6.39% and in the orange class (class 1) by 4.66%. However, an increase in HF risk perceptions decreases the probability of being in the green class (class 3) by 5.12% and in the yellow class (class 4) by 5.93%. Similarly, the orange (class 1) socioeconomic class, which is characterised by its strong pro-clean energy position, is positively related to support for renewable energy. Thus, an increase in support for renewable energy increases the probability of an individual being in class 1 (orange) by 4.11% but decreases the probability of being in the yellow class (class 4) by 3.20%. As noted by Brunner & Axsen, (2020) and Thomas et al. (2017), when compared to renewable energy sources, non-renewable energy sources have lower support. Our results reveal that support for HF activities is inversely correlated with support for renewable energy sources, with variations seen across different segments of the population.

People's views on how important HF is to the national economy are linked to their support for HF. An increase in an individual’s perception about the economic importance of HF increases the probability of being in class 3 (green) by 1.54% and in class 4 (yellow) by 4.50%. However, it decreases the probability of being in class 1 (orange) by 3.75% and in class 2 (red) by 2.77%. Finally, on the energy-related covariates, trust in the oil and gas industry is positively associated with support for HF activities. Specifically, an increase in an individual’s trust in the energy industry increases the probability of being in the green class (class 3) by 1.31% and in the yellow class (class 4) by 2.07%. However, an increase in a person’s trust in the industry decreases the probability of being in class 2 (red) by 2.87%. Knoblauch et al. (2019) noted a positive relationship between trust in the energy industry and support for energy technologies. However, after controlling for several HF project features, Lokuge et al. (2023) did not find any significant relation between the two. Our findings indicate that the influence of confidence in the oil and gas industry on the level of support for HF varies depending on the specific segment of the population a person belongs to. To better highlight the distinctions and profiles of the various classes, insights were drawn from all three models to provide additional class descriptions (aliases) for the various classes. Class 1 (orange) was described as the clean energy group, class 2 (red) as HF protesters, class 3 (green) as HF lovers, and class 4 (yellow) as the benefits group.

This analysis suggests that HF advocates (green) are more likely to be males in rural areas who have high experience in the energy industry, perceive HF as an acceptable means of oil and gas extraction, are less worried about the negative effects of HF, consider it to be less dangerous, and have a high level of trust in the oil and gas industry. Protesters of HF (red), on the other hand, are more likely to be highly educated females who are very concerned about the negative impacts of HF, see it as a bad means of oil and gas extraction that is not important to the national economy, and have less trust in the oil and gas industry. Individuals in the benefits (yellow) class are more likely to be old, very experienced in the energy industry, have less concern about HF's negative impacts, see it as an acceptable means of oil and gas extraction that is less risky and economically important, and have a high level of trust in the oil and gas industry. Finally, the orange class (clean energy) consists of individuals who are more likely to be females in urban areas, have less experience in the oil and gas industry, are very concerned about the negative impacts of HF, see it as a terrible means of oil and gas extraction that is risky and not important to the national economy, and have staunch support for renewable energy sources.

5.0 Conclusion and Policy Implications

The heterogeneity in public perceptions of HF is not surprising considering the contradictory evidence of those perceptions in the literature. However, it appears that the majority of the people are willing to at least accept some form of HF development in their local communities. The four distinct segments of the population identified in this study provide insights into the contradictory evidence of HF acceptance. Across the latent classes, economic benefits to the community, citizen consultation on HF, proximity, and the likelihood and severity of HF-induced seismicity had the largest effects on individuals' support ratings of proposed HF projects.

Despite indicating the highest support for HF, the green (HF lovers) class has a strong sensitivity to the risks of HF-induced earthquakes relative to the other classes. The yellow (benefits) class is characterised by its concern for their community's economic benefits and transparent public consultations as part of the planning of HF projects in their local communities. Similarly, the orange (clean energy) class rating of HF scenarios hinges on proximity (NIMBY), community consultation, and HF-induced earthquake risks. Surprisingly, despite their rejection of many forms of HF, members of the red class were the least sensitive to the idea of HF-induced earthquakes.

Other survey-based class-defining variables indicate that proponents of HF are more likely to be men living in rural areas who have a high level of education and knowledge about the energy sector, who view HF as a viable method for extracting oil and gas, who worry less about the potential negative consequences of HF, who view it as less dangerous, and who have a great deal of faith in the oil and gas industry. Conversely, HF protesters tend to be college-educated women who are particularly worried about the negative effects of HF, see HF as a lousy method of oil and gas production that is not crucial to the national economy, and have less faith in the oil and gas sector. People who fall into the "benefits" (yellow) segment tend to be older and more seasoned energy workers who are less worried about HF's negative effects, and who view it as a reasonable method of oil and gas extraction because it is less risky and economically significant, and who have a great deal of faith in the oil and gas industry. Finally, the orange class (clean energy) is made up of urban women with less oil and gas industry experience who are deeply concerned about HF's negative effects, view it as a risky and unnecessary method of extracting oil and gas, and are instead committed to developing renewable sources of energy.

Proximity, procedural and distributive justice concerns, as well as concerns about induced seismicity, have been repeatedly identified by scholars as significant, interrelated, and long-lasting determinants of HF support (Chewinski et al., 2023; Hoen et al., 2019; Lokuge et al., 2023; Walker & Baxter, 2017). Our contribution to the existing literature involves the identification and characterization of four distinctive groups of individuals who exhibit different levels of worry about seismicity, proximity, compensation, and justice-related problems in the context of hypothetical HF project development. It is suggested that variations in support for essential attributes of HF projects may be influenced by distinct concerns pertaining to seismicity, pollution, lack of confidence in the oil and gas industry, considerations about community benefits and proximity of HF project development. The findings of our LCA indicate that people do not form a homogeneous group. Instead, they are motivated by distinct issues that lawmakers and HF project developers must consider. Our study of public perceptions of HF in western Canada highlighted the need to recognise the diversity of opinions among the population. Despite this diversity, the majority of our sample is mostly in agreement on the growth of HF in the region. Within the various classes, however, there is a consistent and unanimous rejection of HF project scenarios that include characteristics such as the potential to induce seismic activity, lack of compensation, and absence of consultation.

These results offer compelling evidence for individuals' heterogeneity in their preferences for energy technologies (HF). This also provides a plausible rationale for the debates in the literature on the public's perceptions of HF. This study is among the first in the economics literature to use LCA of vignette ratings instead of the traditional stated preference techniques to explore the heterogeneity of individuals' preferences for HF. This research provides a starting point for thinking about how to accommodate the diversity of opinions around HF as we design the energy infrastructure of the future.

Of course, more research is needed to confirm the evidence presented here. Our study could not explore the marginal effects of the vignette attributes, which will provide more information about the sensitivity of the various classes to those attributes. It is, therefore, important to use care while interpreting the outcomes of the vignette. The findings presented in this study are subject to other several constraints, mostly stemming from the wide geographic distribution of our survey participants, who are spread across a province of considerable size. Although the scenarios were evaluated uniformly, it is important to note that the respondents were geographically dispersed and may possess traits that extend beyond the scope of this study. In addition, it is worth noting that while participants in our study expressed acceptance towards certain hypothetical designs of HF projects, it is important to acknowledge that the process of siting and approving HF projects in Canada is progressively intricate and regulated. This is, however, a useful start for the empirical application of LCA to vignette experiments.

References

Aitken, M. (2010). Wind power and community benefits: Challenges and opportunities. *Energy Policy*, *38*(10), 6066–6075. https://doi.org/10.1016/j.enpol.2010.05.062

Alberta Energy Regulator. (2015). *Subsurface Orders*. https://www.aer.ca/regulating-development/compliance/orders/subsurface-orders

Anderson, B., & Coletto, D. (2016). Release PUBLIC PERSPECTIVES ON CANADA'S OIL RESOURCES. *Abacus Data*, 1–9. http://abacusdata.ca/wp-content/uploads/2016/11/Abacus-Release-_energy_FINAL.pdf

Anderson, B. J., & Theodori, G. L. (2009). Local Leaders' Perceptions of Energy Development in the Barnett Shale. *Southern Rural Sociology*, *24*(1), 113–129. http://search.proquest.com/socscijournals/docview/213118552/abstract

Ankenman, B. E. (1999). Design of Experiments with Two- and Four-Level Factors. *Journal of Quality Technology*, *31*(4), 363–375. https://doi.org/10.1080/00224065.1999.11979943

Atherton, F., & Macintosh, C. (2014). *Report of the Nova Scotia Independent Review Panel on Hydraulic Fracturing*. 387.

Atkinson, G. M., Eaton, D. W., Ghofrani, H., Walker, D., Cheadle, B., Schultz, R., Shcherbakov, R., Tiampo, K., Gu, J., Harrington, R. M., Liu, Y., van der Baan, M., & Kao, H. (2016). Hydraulic fracturing and seismicity in the western Canada sedimentary basin. *Seismological Research Letters*, *87*(3), 631–647. https://doi.org/10.1785/0220150263

Auspurg, K., & Hinz, T. (2015a). Multifactorial Experiments in Surveys : Conjoint Analysis, Choice Experiments, and Factorial Surveys. *Experimente in Den Sozialwissenschaften*, *1*(ISBN 978-3-8487-1916-7), 291–315.

Auspurg, K., & Hinz, T. (2015b). Setting Up the Survey. *Factorial Survey Experiments*, 60–84. https://doi.org/10.4135/9781483398075.n4

Auspurg, K., & Jäckle, A. (2017). First Equals Most Important? Order Effects in Vignette-Based Measurement. *Sociological Methods and Research*, *46*(3), 490–539. https://doi.org/10.1177/0049124115591016

Axsen, J. (2014). Citizen acceptance of new fossil fuel infrastructure: Value theory and Canada's northern gateway pipeline. *Energy Policy*, *75*, 255–265. https://doi.org/10.1016/j.enpol.2014.10.023

Baka, J., Hesse, A., Weinthal, E., & Bakker, K. (2019). Environmental Knowledge Cartographies: Evaluating Competing Discourses in U.S. Hydraulic Fracturing Rule-Making. *Annals of the American Association of Geographers*, *109*(6), 1941–1960. https://doi.org/10.1080/24694452.2019.1574549

Bandelow, N. C., Hornung, J., Schröder, I., & Vogeler, C. S. (2022). Hydraulic fracturing, polarization, and environmental policy implementation. *Review of Policy Research*, *39*(4), 384–386. https://doi.org/10.1111/ropr.12491

Bayer, P., & Ovodenko, A. (2019). Many voices in the room: A national survey experiment on how framing changes views toward fracking in the United States. *Energy Research and Social Science*, *56*(May), 101213. https://doi.org/10.1016/j.erss.2019.05.023

Bazilian, M., Perdersen, A., & Baranes, E. (2013). Considering shale gas in Europe. *European Energy Journal*, *3*(1), 37–63.

BC Oil and Gas Commission. (2015). *Introduction to Chemical Use*. FracFocus Chemical Disclosure Registry. http://www.fracfocus.ca/en/chemical-use/introduction- chemical-use%0ABC

Borriello, A., Burke, P. F., & Rose, J. M. (2021). If one goes up, another must come down: A latent class hybrid choice modelling approach for understanding electricity mix preferences among renewables and non-renewables. *Energy Policy*, *159*(December). https://doi.org/10.1016/j.enpol.2021.112611

Boudet, H., Bugden, D., Zanocco, C., & Maibach, E. (2016). The effect of industry activities on public support for 'fracking.' *Environmental Politics*, *25*(4), 593–612. https://doi.org/10.1080/09644016.2016.1153771

Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C., & Leiserowitz, A. (2014). "Fracking" controversy and communication: Using national survey data to understand public perceptions of hydraulic fracturing. *Energy Policy*, *65*, 57–67. https://doi.org/10.1016/j.enpol.2013.10.017

Boudet, H. S., & Ortolano, L. (2010). A tale of two sitings: Contentious politics in liquefied natural gas facility siting in California. *Journal of Planning Education and Research*, *30*(1), 5–21. https://doi.org/10.1177/0739456X10373079

Boyle, K. J. (2017). *Contingent Valuation in Practice*. https://doi.org/10.1007/978-94-007-7104-8_4

Brennan, N., & Van Rensburg, T. M. (2016). Wind farm externalities and public preferences for community consultation in Ireland: A discrete choice experiments approach. *Energy Policy*, *94*, 355–365. https://doi.org/10.1016/j.enpol.2016.04.031

Brunner, T., & Axsen, J. (2020). Oil sands, pipelines and fracking: Citizen acceptance of unconventional fossil fuel development and infrastructure in Canada. *Energy Research and Social Science*, *67*(March), 101511. https://doi.org/10.1016/j.erss.2020.101511

Cama, T. (2015). “Maryland bans fracking.” *The Hill*.

CAPP. (2019). *Industry Shared Practices Anomalous Induced Seismicity due to Hydraulic Fracturing The Canadian Association of Petroleum Producers (CAPP) represents companies , large*. *April*.

Chewinski, M., Anders, S., & Parkins, J. R. (2023). Agricultural landowner perspectives on wind energy development in Alberta, Canada: insights from the lens of energy justice and democracy. *Environmental Sociology*, *00*(00), 1–13. https://doi.org/10.1080/23251042.2023.2247627

Choma, B. L., Hanoch, Y., & Currie, S. (2016). Attitudes toward hydraulic fracturing: The opposing forces of political conservatism and basic knowledge about fracking. *Global Environmental Change*, *38*, 108–117. https://doi.org/10.1016/j.gloenvcha.2016.03.004

Clarke, C. E., Budgen, D., Hart, P. S., Stedman, R. C., Jacquet, J. B., Evensen, D. T. N., & Boudet, H. S. (2016). How geographic distance and political ideology interact to influence public perception of unconventional oil/natural gas development. *Energy Policy*, *97*, 301–309. https://doi.org/10.1016/j.enpol.2016.07.032

Colborn, T., Kwiatkowski, C., Schultz, K., & Bachran, M. (2011). Hazard assessment articles natural gas operations from a public health perspective. *Human and Ecological Risk Assessment*, *17*(5), 1039–1056. https://doi.org/10.1080/10807039.2011.605662

Czolowski, E. D., Santoro, R. L., Srebotnjak, T., & Shonkoff, S. B. C. (2017). Toward consistent methodology to quantify populations in proximity to oil and gas development: A national spatial analysis and review. *Environmental Health Perspectives*, *125*(8), 1–11. https://doi.org/10.1289/EHP1535

Dallenes, H., Geerts, R., Vandermoere, F., & Verbist, G. (2023). The Energy Mix: Understanding People's Diverging Energy Preferences in Belgium. *Social Sciences*, *12*(5). https://doi.org/10.3390/socsci12050260

Davies, R., Foulger, G., Bindley, A., & Styles, P. (2013). Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons. *Marine and Petroleum Geology*, *45*, 171–185. https://doi.org/10.1016/j.marpetgeo.2013.03.016

Davis, C., & Fisk, J. M. (2014). Energy Abundance or Environmental Worries? Analyzing Public Support for Fracking in the United States. *Review of Policy Research*, *31*(1), 1–16. https://doi.org/10.1111/ropr.12048

DEC, NYS. (2011). Revised draft supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program: Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low-permea. *New York State Department of Environmental Conservation, Albany, NY.*

Drohan, P. J., Brittingham, M., Bishop, J., & Yoder, K. (2012). Early trends in landcover change and forest fragmentation due to shale-gas development in Pennsylvania: A potential outcome for the northcentral appalachians. *Environmental Management*, *49*(5), 1061–1075. https://doi.org/10.1007/s00267-012-9841-6

Drummond, V., & Grubert, E. (2017). Fault lines: Seismicity and the fracturing of energy narratives in Oklahoma. *Energy Research and Social Science*, *31*(June), 128–136. https://doi.org/10.1016/j.erss.2017.05.039

Ekos. (2016). *Canadian Attitudes toward Energy and Pipelines*. 1–21.

Esswein, E. J., Breitenstein, M., Snawder, J., Kiefer, M., & Sieber, W. K. (2013). Occupational exposures to respirable crystalline silica during hydraulic fracturing. *Journal of Occupational and Environmental Hygiene*, *10*(7), 347–356. https://doi.org/10.1080/15459624.2013.788352

Evensen, D., Jacquet, J. B., Clarke, C. E., & Stedman, R. C. (2014). What's the "fracking" problem? One word can't say it all. *Extractive Industries and Society*, *1*(2), 130–136. https://doi.org/10.1016/j.exis.2014.06.004

Evensen, D., Varley, A., Whitmarsh, L., Devine-Wright, P., Dickie, J., Bartie, P., Napier, H., Mosca, I., Foad, C., & Ryder, S. (2022). Effect of linguistic framing and information provision on attitudes towards induced seismicity and seismicity regulation. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-15448-4

García, J. H., Cherry, T. L., Kallbekken, S., & Torvanger, A. (2016). Willingness to accept local wind energy development: Does the compensation mechanism matter? *Energy Policy*, *99*, 165–173. https://doi.org/10.1016/j.enpol.2016.09.046

Goldstein, H. (2007). *Helsinki Centre for Multilevel Modelling University of Bristol Introduction Introduction*. 1–70.

Gravelle, T. B., & Lachapelle, E. (2015). Politics, proximity and the pipeline: Mapping public attitudes toward Keystone XL. *Energy Policy*, *83*, 99–108. https://doi.org/10.1016/j.enpol.2015.04.004

Greene, W. H., & Hensher, D. A. (2003). A latent class model for discrete choice analysis: Contrasts with mixed logit. *Transportation Research Part B: Methodological*, *37*(8), 681–698. https://doi.org/10.1016/S0191-2615(02)00046-2

Gunzburger, Y., Agnoletti, M. F., Deshaies, M., Ferey, S., & Raggi, P. (2017). Social perception of unconventional gas extraction on the outskirts of a former coal-mining area in Northeast France. *Extractive Industries and Society*, *4*(1), 53–62. https://doi.org/10.1016/j.exis.2016.12.006

Hainmueller, J., Hangartner, D., & Yamamoto, T. (2015). Validating vignette and conjoint survey experiments against real-world behavior. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(8), 2395–2400. https://doi.org/10.1073/pnas.1416587112

Hess, J. H., Manning, D. T., Iverson, T., & Cutler, H. (2019). Uncertainty, learning, and local opposition to hydraulic fracturing. *Resource and Energy Economics*, *55*, 102–123. https://doi.org/10.1016/j.reseneeco.2018.11.001

Hess, S., & Train, K. (2017). Correlation and Scale in Mixed logit Models. *Choice Modelling*, *23*, 1–8.

Hoen, B., Firestone, J., Rand, J., Elliot, D., Hübner, G., Pohl, J., Wiser, R., Lantz, E., Haac, T. R., & Kaliski, K. (2019). Attitudes of U.S. Wind Turbine Neighbors: Analysis of a Nationwide Survey. *Energy Policy*, *134*(August), 110981. https://doi.org/10.1016/j.enpol.2019.110981

Holeczek, N. (2019). Hazardous materials truck transportation problems: A classification and state of the art literature review. *Transportation Research Part D: Transport and Environment*, *69*(March), 305–328. https://doi.org/10.1016/j.trd.2019.02.010

Howarth, R. W., Santoro, R., & Ingraffea, A. (2012). Venting and leaking of methane from shale gas development: Response to Cathles et al. *Climatic Change*, *113*(2), 537–549. https://doi.org/10.1007/s10584-012-0401-0

Howell, E. L., Wirz, C. D., Brossard, D., Scheufele, D. A., & Xenos, M. A. (2019). Seeing through risk-colored glasses: Risk and benefit perceptions, knowledge, and the politics of fracking in the United States. *Energy Research and Social Science*, *55*(May), 168–178. https://doi.org/10.1016/j.erss.2019.05.020

Huijts, N. M. A., Molin, E. J. E., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews*, *16*(1), 525–531. https://doi.org/10.1016/j.rser.2011.08.018

Hunter, S., & Leyden, K. M. (1995). Beyond NIMBY: Explaining Opposition to Hazardous Waste Facilities. *Policy Studies Journal*, *23*(4), 601–619. https://doi.org/10.1111/j.1541-0072.1995.tb00537.x

Jacquet, J. B. (2012). Landowner attitudes toward natural gas and wind farm development in northern Pennsylvania. *Energy Policy*, *50*, 677–688. https://doi.org/10.1016/j.enpol.2012.08.011

Jantz, C. A., Kubach, H. K., Ward, J. R., Wiley, S., & Heston, D. (2014). Assessing Land Use Changes Due to Natural Gas Drilling Operations in the Marcellus Shale in Bradford County, PA. *The Geographical Bulletin*, *55*, 18–35.

Jerolmack, C., & Walker, E. T. (2018). Please in my backyard: Quiet mobilization in support of fracking in an appalachian community. *American Journal of Sociology*, *124*(2). https://doi.org/10.1086/698215

Johnston, R. J., Boyle, K. J., Vic Adamowicz, W., Bennett, J., Brouwer, R., Ann Cameron, T., Michael Hanemann, W., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., & Vossler, C. A. (2017). Contemporary guidance for stated preference studies. *Journal of the Association of Environmental and Resource Economists*, *4*(2), 319–405. https://doi.org/10.1086/691697

Kácha, O., Vintr, J., & Brick, C. (2022). Four Europes: Climate change beliefs and attitudes predict behavior and policy preferences using a latent class analysis on 23 countries. *Journal of Environmental Psychology*, *81* (September 2021). https://doi.org/10.1016/j.jenvp.2022.101815

Kaplan, T. (2014). “Citing health risks, Cuomo bans fracking in New York State.” *New York Times*, 17.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., Kasperson, J. X., & Ratick, S. (1988). The Social Amplification of Risk: A Conceptual Framework. *Risk Analysis*, *8*(2), 177–187. https://doi.org/10.1111/j.1539-6924.1988.tb01168.x

Kassotis, C. D., Tillitt, D. E., Davis, J. W., Hormann, A. M., & Nagel, S. C. (2014). Estrogen and androgen receptor activities of hydraulic fracturing chemicals and surface and ground water in a drilling-dense region. *Endocrinology*, *155*(3), 897–907. https://doi.org/10.1210/en.2013-1697

Keeney, R. L., von Winterfeldt, D., & Eppel, T. (1990). Eliciting Public Values for Complex Policy Decisions. *Management Science*, *36*(9), 1011–1030. https://doi.org/10.1287/mnsc.36.9.1011

Kemball-Cook, S., Bar-Ilan, A., Grant, J., Parker, L., Jung, J., Santamaria, W., Mathews, J., & Yarwood, G. (2010). Ozone impacts of natural gas development in the Haynesville Shale. *Environmental Science and Technology*, *44*(24), 9357–9363. https://doi.org/10.1021/es1021137

Kerr, S., Johnson, K., & Weir, S. (2017). Understanding community benefit payments from renewable energy development. *Energy Policy*, *105*(February), 202–211. https://doi.org/10.1016/j.enpol.2017.02.034

Khan, S., Maoh, H., & Dimatulac, T. (2021). The demand for electrification in Canadian fleets: A latent class modeling approach. *Transportation Research Part D: Transport and Environment*, *90*(December 2020), 102653. https://doi.org/10.1016/j.trd.2020.102653

Kim, W. Y. (2013). Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. *Journal of Geophysical Research: Solid Earth*, *118*(7), 3506–3518. https://doi.org/10.1002/jgrb.50247

Kim, Y., Kim, W., & Kim, M. (2014). An international comparative analysis of public acceptance of nuclear energy. *Energy Policy*, *66*, 475–483. https://doi.org/10.1016/j.enpol.2013.11.039

Klick, H., & Smith, E. R. A. N. (2010). Public understanding of and support for wind power in the United States. *Renewable Energy*, *35*(7), 1585–1591. https://doi.org/10.1016/j.renene.2009.11.028

Knoblauch, T. A. K., Trutnevyte, E., & Stauffacher, M. (2019). Siting deep geothermal energy: Acceptance of various risk and benefit scenarios in a Swiss-German cross-national study. *Energy Policy*, *128*(January 2018), 807–816. https://doi.org/10.1016/j.enpol.2019.01.019

Kohut, A., Doherty, C., Dimock, M., & Keeter, S. (2012). As Gas Prices Pinch, Support for Oil and Gas Production Grows. *The Pew Research Center*, *202*.

Kriesky, J., Goldstein, B. D., Zell, K., & Beach, S. (2013). Differing opinions about natural gas drilling in two adjacent counties with different levels of drilling activity. *Energy Policy*, *58*, 228–236. https://doi.org/10.1016/j.enpol.2013.03.005

Lachapelle, E. (2014). *Issues in Energy and Environmental Policy Public Opinion on Hydraulic Fracturing in the Province of Quebec : Authors*. *17*.

Lachapelle, E., Kiss, S., & Montpetit, É. (2018). Public perceptions of hydraulic fracturing (Fracking) in Canada: Economic nationalism, issue familiarity, and cultural bias. *Extractive Industries and Society*, *5*(4), 634–647. https://doi.org/10.1016/j.exis.2018.07.003

Lachapelle, E., Montpetit, É., & Gauvin, J. P. (2014). Public Perceptions of Expert Credibility on Policy Issues: The Role of Expert Framing and Political Worldviews. *Policy Studies Journal*, *42*(4), 674–697. https://doi.org/10.1111/psj.12073

Langer, K., Decker, T., Roosen, J., & Menrad, K. (2016). A qualitative analysis to understand the acceptance of wind energy in Bavaria. *Renewable and Sustainable Energy Reviews*, *64*(2016), 248–259. https://doi.org/10.1016/j.rser.2016.05.084

Li, T. H. Y., Ng, S. T., & Skitmore, M. (2013). Evaluating stakeholder satisfaction during public participation in major infrastructure and construction projects: A fuzzy approach. *Automation in Construction*, *29*, 123–135. https://doi.org/10.1016/j.autcon.2012.09.007

Liebe, U., & Dobers, G. M. (2019). Decomposing public support for energy policy: What drives acceptance of and intentions to protest against renewable energy expansion in Germany? *Energy Research and Social Science*, *47*(August 2018), 247–260. https://doi.org/10.1016/j.erss.2018.09.004

Liebe, U., Moumouni, I. M., Bigler, C., Ingabire, C., & Bieri, S. (2020). Using Factorial Survey Experiments to Measure Attitudes, Social Norms, and Fairness Concerns in Developing Countries. *Sociological Methods and Research*, *49*(1), 161–192. https://doi.org/10.1177/0049124117729707

Lienhoop, N. (2018). Acceptance of wind energy and the role of financial and procedural participation: An investigation with focus groups and choice experiments. *Energy Policy*, *118*(April), 97–105. https://doi.org/10.1016/j.enpol.2018.03.063

Lits, B. (2021). Exploring astroturf lobbying in the EU: The case of responsible energy citizen coalition. *European Policy Analysis*, *7*(1). https://doi.org/10.1002/epa2.1086

Lokuge, N., Phillips, J., Anders, S., & Baan, M. Van Der. (2023). Human-induced seismicity and the public acceptance of hydraulic fracturing : A vignette experiment. *The Extractive Industries and Society*, *15*(March), 101335. https://doi.org/10.1016/j.exis.2023.101335

Magidson, J., & Vermunt, J. K. (2007). Use of latent class regression models with a random intercept to remove the effects of the overall response rating level. *Compstat 2006 - Proceedings in Computational Statistics*, 351–360. https://doi.org/10.1007/978-3-7908-1709-6_27

Malewitz, J. (2015). "Abbott signs" Denton Fracking Bill.". *The Texas Tribune*, 18.

Mccleary, W. K., & Coupe, P. (2022). *Fracking promises prosperity — but what if it ' s happening in your front yard ?*

McComas, K. A., Lu, H., Keranen, K. M., Furtney, M. A., & Song, H. (2016). Public perceptions and acceptance of induced earthquakes related to energy development. *Energy Policy*, *99*, 27–32. https://doi.org/10.1016/j.enpol.2016.09.026

McCutcheon, A. (2011). Latent Class Analysis. In *Latent Class Analysis*. https://doi.org/10.4135/9781412984713.n2

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of Applied Econometrics*, *15*(5), 447–470. https://doi.org/10.1002/1099-1255(200009/10)15:5<447::aid-jae570>3.0.co;2-1

McFadden, D., & Zarembka, P. (1974). Conditional Logit Analysis Of Qualitative Choice Behavior. *Frontiers in Econometrics*, 105–142.

McGlade, C., & Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature*, *517*(7533), 187–190. https://doi.org/10.1038/nature14016

McLaughlin, D. M., & Cutts, B. B. (2018). Neither Knowledge Deficit nor NIMBY: Understanding Opposition to Hydraulic Fracturing as a Nuanced Coalition in Westmoreland County, Pennsylvania (USA). *Environmental Management*, *62*(2), 305–322. https://doi.org/10.1007/s00267-018-1052-3

Mooney, R., Boudet, H. S., & Hazboun, S. O. (2022). Risk-benefit perceptions of natural gas export in Oregon. *Local Environment*, *27*(3), 342–356. https://doi.org/10.1080/13549839.2022.2040470

Motz, A. (2021). Security of supply and the energy transition: The households' perspective investigated through a discrete choice model with latent classes. *Energy Economics*, *97*, 105179. https://doi.org/10.1016/j.eneco.2021.105179

Muthén, B. (2004). Latent variable analysis. In *The Sage handbook of quantitative methodology for the social sciences* (Vol. 13, Issue 345(368)).

Myers, T. (2012). Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers. *Ground Water*, *50*(6), 872–882. https://doi.org/10.1111/j.1745-6584.2012.00933.x

National Energy Board. (2011). Tight Oil Developments in the Western Canada sedimentary basin. *Energy Briefing Note*.

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. *Structural Equation Modeling*, *14*(4), 535–569. https://doi.org/10.1080/10705510701575396

Nylund-Gibson, K., Garber, A. C., Singh, J., Witkow, M. R., Nishina, A., & Bellmore, A. (2022). The Utility of Latent Class Analysis to Understand Heterogeneity in Youth Coping Strategies:

A Methodological Introduction. *Behavioral Disorders*. https://doi.org/10.1177/01987429211067214

O'Connor, C. D., & Fredericks, K. (2018). Citizen perceptions of fracking: The risks and opportunities of natural gas development in Canada. *Energy Research and Social Science*, *42*(June 2017), 61–69. https://doi.org/10.1016/j.erss.2018.03.005

Olive, A. (2016). *What is the fracking story in Canada?*

Palliser, J. (2011). Fracking fury. *Green Science*, 20–25.

Parkins, J. R., Anders, S., Meyerhoff, J., & Holowach, M. (2021). Landowner acceptance of wind turbines on their land: Insights from a factorial survey experiment. *Land Economics*, 012521-0008R1. https://doi.org/10.3368/le.98.4.012521-0008r1

Phillips, J. N. (2021). Public Perception of Hydraulic Fracturing and the Oil and Gas Industry in Western Canada: What the Frack is Going On?

Popkin, J. H., Duke, J. M., Borchers, A. M., & Ilvento, T. (2013). Social costs from proximity to hydraulic fracturing in New York State. *Energy Policy*, *62*, 62–69. https://doi.org/10.1016/j.enpol.2013.07.080

Qi, M., Li, X., Liu, S., Li, Y., & Huang, W. (2020). Impact of the COVID-19 epidemic on patterns of pregnant women's perception of threat and its relationship to mental state: A latent class analysis. *PLoS ONE*, *15*(10 October), 1–15. https://doi.org/10.1371/journal.pone.0239697

Randeree, K., & Faramawy, A. T. el. (2011). Islamic perspectives on conflict management within project managed environments. *International Journal of Project Management*, *29*(1), 26–32. https://doi.org/10.1016/j.ijproman.2010.01.013

Read, S., Erens, B., Wittenberg, R., Wistow, G., Dickinson, F., Knapp, M., Cyhlarova, E., & Mays, N. (2021). Public preferences for paying for social care in later life in England: A latent class analysis. *Social Science and Medicine*, *274*(February), 113803. https://doi.org/10.1016/j.socscimed.2021.113803

Renn, O., Siovic, P., Burns, W. J., Kasperson, J. X., & Kasperson, R. E. (1992). Social amplification theory: Theoretical foundations and empirical applications. *Journal of Social Issues*, *48*(4), 127–160.

Ritchie, L. A., Long, M. A., Leon-Corwin, M., & Gill, D. A. (2021). Citizen perceptions of fracking-related earthquakes: Exploring the roles of institutional failures and resource loss in Oklahoma, United States. *Energy Research and Social Science*, *80*. https://doi.org/10.1016/j.erss.2021.102235

Roy, A. A., Adams, P. J., & Robinson, A. L. (2014). Air pollutant emissions from the development, production, and processing of Marcellus Shale natural gas. *Journal of the Air and Waste Management Association*, *64*(1), 19–37. https://doi.org/10.1080/10962247.2013.826151

Royal Society. (2012). *Shale gas extraction in the UK: a review of hydraulic fracturing*. *June*. https://royalsociety.org/~/media/policy/projects/shale-gas-extraction/2012-06-28-shale-gas.pdf

Rozell, D. J., & Reaven, S. J. (2012). Water Pollution Risk Associated with Natural Gas Extraction from the Marcellus Shale. *Risk Analysis*, *32*(8), 1382–1393. https://doi.org/10.1111/j.1539-6924.2011.01757.x

Rubinstein, J. L., & Mahani, A. B. (2015). Myths and facts on wastewater injection, hydraulic fracturing, enhanced oil recovery, and induced seismicity. *Seismological Research Letters*, *86*(4), 1060–1067. https://doi.org/10.1785/0220150067

Scarpa, R., Gilbride, T. J., Campbell, D., & Hensher, D. A. (2009). Modelling attribute non-attendance in choice experiments for rural landscape valuation. *European Review of Agricultural Economics*, *36*(2), 151–174. https://doi.org/10.1093/erae/jbp012

Schafft, K. A., & Biddle, C. (2015). Opportunity, ambivalence, and youth perspectives on community change in Pennsylvania's Marcellus Shale region. *Human Organization*, *74*(1), 74–85. https://doi.org/10.17730/humo.74.1.6543u2613xx23678

Sherren, K., Parkins, J. R., Owen, T., & Terashima, M. (2019). Does noticing energy infrastructure influence public support for energy development? Evidence from a national survey in Canada. *Energy Research and Social Science*, *51*(August 2018), 176–186. https://doi.org/10.1016/j.erss.2019.01.014

Skrondal, A., & Rabe-Hesketh, S. (2004). Generalized latent variable modeling: Multilevel, longitudinal, and structural equation models. *Generalized Latent Variable Modeling: Multilevel, Longitudinal, and Structural Equation Models*, 1–508. https://doi.org/10.1198/tech.2005.s263

Smith, E. R. A. N., Michaud, K. E. H., & Carlisle, J. E. (2010). *What the California Public Thinks About Offshore Oil Development: Past Trends And Future Possiblities, Oil+ Water: The Case of Santa Barbara and Santa California*.

Smith-Spark, L., & Jim, B. (2013, May). "UK lifts ban on fracking to exploit shale gas reserves." *CNN International*. http://edition.cnn.com/2012/12/13/business/ uk-fracking/.

Spence, A., Poortinga, W., Pidgeon, N., & Lorenzoni, I. (2010). Public perceptions of energy choices: The influence of beliefs about climate change and the environment. *Energy and Environment*, *21*(5), 385–407. https://doi.org/10.1260/0958-305X.21.5.385

Statistics Canada. (2019). *Canada at a Glance 2019: Education*. https://www150.statcan.gc.ca/n1/pub/12-581-x/2019001/edu-eng.htm

Statistics Canada. (2021). *Population estimates on July 1st, by age and sex*. https://doi.org/https://doi.org/10.25318/1710000501-eng

Stedman, R. C., Darrick, E., Sarah, O., & Mathew, H. (2016). *Comparing the Relationship between Knowledge and Support for Hydraulic Fracturing between Residents of the United States and the United Kingdom*. *15*(2), 1–23.

Stedman, R. C., Evensen, D., O'Hara, S., & Humphrey, M. (2016). Comparing the relationship between knowledge and support for hydraulic fracturing between residents of the United States and the United Kingdom. *Energy Research and Social Science*, *20*, 142–148. https://doi.org/10.1016/j.erss.2016.06.017

Steinzor, N., Subra, W., & Sumi, L. (2013). Investigating links between shale gas development and health impacts through a community survey project in pennsylvania. *New Solutions*, *23*(1), 55–83. https://doi.org/10.2190/NS.23.1.e

Tan, H., Xu, J., & Wong-Parodi, G. (2019a). The politics of Asian fracking: Public risk perceptions towards shale gas development in China. *Energy Research and Social Science*, *54*(October 2018), 46–55. https://doi.org/10.1016/j.erss.2019.03.007

Tan, H., Xu, J., & Wong-Parodi, G. (2019b). The politics of Asian fracking: Public risk perceptions towards shale gas development in China. *Energy Research and Social Science*, *54*(October 2018), 46–55. https://doi.org/10.1016/j.erss.2019.03.007

Thomas, M., Partridge, T., Harthorn, B. H., & Pidgeon, N. (2017). Deliberating the perceived risks, benefits, and societal implications of shale gas and oil extraction by hydraulic fracturing in the US and UK. *Nature Energy*, *2*(5). https://doi.org/10.1038/nenergy.2017.54

Thomas, M., Pidgeon, N., Evensen, D., Partridge, T., Hasell, A., Enders, C., Herr Harthorn, B., & Bradshaw, M. (2017). Public perceptions of hydraulic fracturing for shale gas and oil in the United States and Canada. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(3), 1–19. https://doi.org/10.1002/wcc.450

Tost, D. (2014). "German government upholds fracking ban." *EurActiv*. http://www.euractiv.com/sections/energy/german-government-upholds- fracking-ban-310127.

Truong, D., Davidson, D. J., & Parkins, J. R. (2019). Context matters: Fracking attitudes, knowledge and trust in three communities in Alberta, Canada. *Extractive Industries and Society*, *6*(4), 1325–1332. https://doi.org/10.1016/j.exis.2019.09.004

Van Rijnsoever, F. J., Van Mossel, A., & Broecks, K. P. F. (2015). Public acceptance of energy technologies: The effects of labeling, time, and heterogeneity in a discrete choice experiment. *Renewable and Sustainable Energy Reviews*, *45*, 817–829. https://doi.org/10.1016/j.rser.2015.02.040

Vermunt, J. K. (1994). General Latent Class Approach To Unobserved Heterogeneity in the. Lc, 1–38.

Vermunt, J. K. (2014). *A general non-parametric approach to the analysis of ordinal categorical data A general non-parametric approach to the analysis of ordinal categorical data*

Vermunt, J. K., & Magidson, J. (2016). *Technical Guide for Latent GOLD Choice 5.1: Basic, Advanced and Syntax*. *617*, 167.

Vermunt, J. K., Magidson, J., Data, T., Magidson, J., & Vermunt, J. K. (2016). Technical Guide for Latent GOLD Choice 5.1: Basic, Advanced and Syntax. *Compstat 2006 - Proceedings in Computational Statistics*, *Lc*, 167. https://doi.org/10.1007/978-3-7908-1709-6_27

Walker, C., & Baxter, J. (2017). Procedural justice in Canadian wind energy development: A comparison of community-based and technocratic siting processes. *Energy Research and Social Science*, *29*(February), 160–169. https://doi.org/10.1016/j.erss.2017.05.016

Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). Impacts of shale gas wastewater disposal on water quality in Western Pennsylvania. *Environmental Science and Technology*, *47*(20), 11849–11857. https://doi.org/10.1021/es402165b

Weller, B. E., Bowen, N. K., & Faubert, S. J. (2020). Latent Class Analysis: A Guide to Best Practice. *Journal of Black Psychology*, *46*(4), 287–311. https://doi.org/10.1177/0095798420930932

Westlake, S., John, C. H. D., & Cox, E. (2023). Perception spillover from fracking onto public perceptions of novel energy technologies. *Nature Energy*, *8*(2), 149–158. https://doi.org/10.1038/s41560-022-01178-4

Whitfield, S. C., Rosa, E. A., Dan, A., & Dietz, T. (2009). *The future of nuclear power: value orientations and risk perception, Risk Anal. 29*, 425–437. https://doi.org/10. 1111/j.1539-6924.2008.01155.x.

Williams, L., Macnaghten, P., Davies, R., & Curtis, S. (2017). Framing 'fracking': Exploring public perceptions of hydraulic fracturing in the United Kingdom. *Public Understanding of Science*, *26*(1), 89–104. https://doi.org/10.1177/0963662515595159

Willits, F. K., Theodori, G. L., & Luloff, A. E. (2016). Correlates of perceived safe uses of hydraulic fracturing wastewater: Data from the Marcellus Shale. *Extractive Industries and Society*, *3*(3), 727–735. https://doi.org/10.1016/j.exis.2016.03.008

Willow, A. J., Zak, R., Vilaplana, D., & Sheeley, D. (2014). The contested landscape of unconventional energy development: A report from Ohio's shale gas country. *Journal of Environmental Studies and Sciences*, *4*(1), 56–64. https://doi.org/10.1007/s13412-013-0159-3

Wynne, B. (1983). Redefining the issues of risk and public acceptance. The social viability of technology. *Futures*, *15*(1), 13–32. https://doi.org/10.1016/0016-3287(83)90070-8

Wynveen, B. J. (2011). a Thematic Analysis of Local Respondents' Perceptions of Barnett Shale Energy Development. *Journal of Rural Social Sciences*, *26*(1), 8–31.

Appendices

Table 13: Results of the random effects model without extreme ratings

Variables _	Without Protest ratings	Without all Extremes
Implementation		
gov't-industry partnership	0.091	0.131**
	(0.060)	(0.065)
fed gov't	0.087	0.115*
	(0.060)	(0.065)
Proximity		
between 50 km and 100 km	0.107*	0.147**
	(0.060)	(0.063)
more than 100 km	0.184***	0.249***
	(0.059)	(0.066)
Capacity		
10% of hh emissions	-0.020	-0.025
	(0.058)	(0.064)
20% of hh emissions	0.052	0.012
	(0.061)	(0.064)
Source		
domestic and the Netherlands	-0.549***	-0.769***
	(0.089)	(0.101)
domestic and the UK	-0.493***	-0.711***
	(0.090)	(0.098)
domestic and Norway	-0.452***	-0.596***
	(0.085)	(0.090)
domestic and the US	-0.482***	-0.619***
	(0.089)	(0.098)
domestic and Germany	-0.550***	-0.769***
	(0.090)	(0.101)
Consultation		
only relevant NGOs	0.098	0.099
	(0.084)	(0.090)
only residents of directly affected communities	0.246***	0.295***
	(0.082)	(0.087)
residents of surrounding communities	0.228***	0.250***
	(0.083)	(0.087)
all residents in the province	0.312***	0.378***
	(0.085)	(0.090)
a national consultation	0.271***	0.337***
	(0.083)	(0.086)
Information		
only at regulatory approval stage	0.429***	0.548***
	(0.062)	(0.065)
throughout the plant's lifespan	0.507***	0.598***
	(0.061)	(0.066)

Benefits		
contract preference for local businesses	0.362***	0.443***
	(0.061)	(0.064)
direct financial compensation to individuals affected	0.524***	0.663***
	(0.064)	(0.069)
Constant	-0.302**	-0.772***
	(0.121)	(0.133)
Number of vignettes	5748	5688
Number of respondents	958	948
Std. dev. random effect (sigma_u)	2.1036	2.0489
Std. dev. error (sigma_e)	1.7811	1.7898
Intra-class correlation (rho)	0.5824	0.5672
Wald chi^2	289.84	290.67

*Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

Table 14: Results of principal component analysis of variables used in the models

Principal component	Variables	Loading	Mean	Std. dev.	Min	Max	kmo
CCS knowledge	CCS capture	0.49	0.562	0.496	0	1	0.611
	CCS tech	0.47	0.459	0.498	0	1	
	CCS storage	0.47	0.685	0.465	0	1	
	CO2 leakage	0.39	0.412	0.492	0	1	
	CCS seismicity	-0.19	0.340	0.474	0	1	
	Ground_H_2O	-0.35	0.517	0.500	0	1	
Perception of environmental risks	Glyphosate	0.34	2.875	0.918	1	4	0.726
	Mobile towers	0.23	2.635	0.896	1	4	
	Wind turbines	0.18	2.449	0.909	1	4	
	Antibiotics	0.39	2.791	0.911	1	4	
	Insecticides	0.29	2.682	0.788	1	4	
	Crime/violence	0.33	2.835	0.788	1	4	
	Drugs	0.32	3.026	0.893	1	4	
	Ozone deplete	0.38	2.870	0.944	1	4	
	Earthquake	0.27	2.578	0.899	1	4	
	Climate change	0.37	2.945	1.012	1	4	
Perception of CCS benefits	Decrease CO_2	0.53	2.564	0.860	1	4	0.655
	Econ. Growth	0.45	2.427	0.881	1	4	
	Envt. Benefit	0.55	2.669	0.925	1	4	
	Cheaper opt.	0.47	2.452	0.898	1	4	
Perception of CCS risks	Promote CO_2	0.41	2.493	0.886	1	4	0.634
	Profit motives	0.50	2.699	0.956	1	4	
	CO_2 leakage	0.56	2.611	0.916	1	4	
	Induced seismic	0.52	2.522	0.892	1	4	

Table 15: Socio-demographic profiles of each class.

Variable	Orange (Clean energy) %	Red (protesters) %	Green (lovers) %	Yellow (benefits) %
Age				
18 – 24	13.1	8.10	4.03	5.28
25 – 34	23.75	27.82	24.91	22.76
35 – 64	53.18	55.64	60.18	59.34
65 – 74	8.36	7.04	7.33	9.76
75 +	1.00	1.41	2.93	2.85
Gender				
Female	48.33	57.83	28.89	38.52
Male	51.67	42.18	71.11	61.48
Place of residence				
Urban	34.90	43.62	48.08	42.50
Rural	65.10	56.38	51.92	57.50
Post-secondary education				
Yes	86.14	91.58	85.34	88.31
No	13.86	8.42	14.66	11.69

Table 16: Results of LCM with demographics as covariates.

Attributes	Orange (clean energy)	Red (protesters)	Green (lovers)	Yellow (benefits)	Wald (=)	p-value
Proximity						
less than 3 km	-0.1791***	-0.1962***	-0.0204	-0.1551***	62.729	0.000
between 3 and 15 km	-0.0064	-0.0461	-0.0145	0.0034		
over 15 km	0.1855***	0.2423***	0.0349**	0.1517***		
Truck Traffic						
up to 10	0.0379**	0.0307	0.0292**	0.0248	6.1988	0.40
10-50	-0.0084	-0.0754**	-0.0068	-0.0155		
over 50	-0.0295**	0.0447*	-0.0225*	-0.0093		
Operation Time						
between 8 am and 8 pm	0.0636***	0.0925***	0.0265**	0.0543***	8.4626	0.037
at all hours of the day	-0.0636***	-0.0925***	-0.0265**	-0.0543***		
Community Consultation						
community not informed of plans	-0.1969***	-0.1777***	-0.0887***	-0.2203***	22.833	0.0066
community informed of plans	0.0294*	0.0434	0.0178	0.0671**		
directly affected landowners consulted during planning	0.0471**	0.0291	0.0169	0.0444*		
full two-way consultation	0.1204***	0.1052***	0.0541**	0.1088***		
Economic Benefits						
no financial benefits	-0.2777***	-0.2401***	-0.1469***	-0.325***	43.9803	0.000
preferential use of local services and employees	0.0808***	0.0371	0.0383**	0.1389***		
donating community grants ranging from $10k to $25k annually	0.016	-0.0101	0.0345**	0.0261		
donating fully funded community projects	0.1809***	0.2132***	0.0741***	0.1601***		
Seismicity						
None-existent	0.2005***	0.199***	0.1211***	0.1616***	13.9671	0.12
too small to be felt	0.145***	0.175***	0.1294***	0.1689***		
persistent and repeating, but too small to cause structural	-0.0171	-0.0572	0.0028	0.0121		
infrequent, but large enough to potentially cause moderate damages	-0.3283***	-0.3167***	-0.2533***	-0.3426***		
Covariates						
Age	-0.0663**	-0.0375	-0.0017	0.1055**	8.1732	0.043
Gender	-0.2229**	-0.6049***	0.7105***	0.1173	50.156	0.000
Urban	0.3524***	-0.0337	-0.2993**	-0.0193	11.9436	0.0076
Post-Secondary	-0.2142*	0.503**	-0.256*	-0.0328	6.8966	0.075
Intercept	0.3408	0.6802**	-0.4563*	-0.5647**	8.4068	0.038

*p-value ≤ 0.1, ** p-value ≤ 0.05 and *** p-value ≤ 0.01

Table 17: Results of LCM with Survey Variables as Covariates.

Attributes	Orange (clean energy)	Red (protesters)	Green (lovers)	Yellow (benefits)	Wald (=)	p-value
Proximity						
less than 3 km	-0.1776***	-0.2245***	-0.0323**	-0.1439***	58.4702	0.000
between 3 and 15 km	-0.0088	-0.0258	-0.0114	0.001		
over 15 km	0.1864***	0.2502**	0.0437***	0.1429***		
Truck Traffic						
up to 10	0.0377**	0.0443	0.0325**	0.0303*	5.8757	0.44
10-50	-0.0144	-0.0886**	-0.0072	-0.0145		
over 50	-0.0232*	0.0443*	-0.0252**	-0.0157		
Operation Time						
between 8 am and 8 pm	0.0675***	0.0903***	0.0231**	0.0525***	9.3809	0.025
at all hours of the day	-0.0675***	-0.0903***	-0.0231**	-0.0525***		
Community Consultation						
community not informed of plans	-0.1884***	-0.1871***	-0.0955***	-0.2225***	21.9001	0.0092
community informed of plans	0.0226	0.026	0.0251	0.0675**		
directly affected landowners consulted during planning	0.0507***	0.0429	0.0214	0.0439*		
full two-way consultation	0.115***	0.1182***	0.049**	0.1111***		
Economic Benefits						
no financial benefits	-0.2752***	-0.2695**	-0.1399***	-0.3214***	51.8991	0.000
preferential use of local services and employees	0.0759***	0.0381	0.0324*	0.1386***		
donating community grants ranging from $10k to $25k annually	0.0212	-0.0171	0.0317*	0.016		
donating fully funded community projects	0.1781***	0.2485***	0.0757***	0.1668***		
Seismicity						
None-existent	0.2041***	0.2128***	0.1066***	0.1637***	18.8398	0.027
too small to be felt	0.1391***	0.1936**	0.1411***	0.1795***		
persistent and repeating, but too small to cause structural	-0.0251*	-0.0364	0.0042	0.01		
infrequent, but large enough to potentially cause moderate damages	-0.3182***	-0.3699***	-0.252***	-0.3532***		
Covariates						
Energy experience	-0.4627***	-0.4681***	0.7016***	0.2292**	22.5592	0.000
HF Concerns	0.051***	0.0688***	-0.1015***	-0.0184**	77.003	0.000
HF Acceptance	-0.1804**	-0.6815***	0.5927***	0.2692***	50.5828	0.000
HF Risk	0.1658**	0.6362***	-0.5505***	-0.2515***	53.8719	0.000
Renewable Energy Support	0.1339***	-0.0709	-0.0175	-0.0455	8.8707	0.031
Economic Importance	-0.142**	-0.3098***	0.2296***	0.2222***	20.0774	0.000
Industrial Trust	0.0106	-0.2424***	0.1485***	0.0833**	24.674	0.000

Economic Reliance Risks	0.0722*	0.0833	-0.0958*	-0.0597	3.63	0.3
Intercept	-0.8928*	1.4951*	-0.2975	-0.3047	3.6188	0.31

*p-value ≤ 0.1, ** p-value ≤ 0.05 and *** p-value ≤ 0.01

CCS Questionnaire & Experimental Designs

Study Title: Public Perceptions of Storing Greenhouse Gas Emissions Underground

Survey Questionnaire

Section 1
In this first section, we will ask you a few questions about the environment you live in.

1. **Which of the following best describes the area you live in?**
    - Urban
    - Suburban
    - Rural

2. **How long have you lived in the area that you currently live in?**
    - Less than 1 year
    - 1-3 years
    - 4-6 years
    - 7-10 years
    - More than 10 years
    - Prefer not to say

3. **Do you own or rent your current residence? For the purpose of the survey, you own your home even if you have outstanding debt that you owe on your mortgage loan.**
    - I own a house
    - I own an apartment
    - I rent a house
    - I rent an apartment
    - I am living at home
    - Other: _____________

4. **Please indicate the extent to which you agree with the following statements.**
    - I feel like I belong to the community where I live
    - I am very attached to the natural environment in my area

- Given the opportunity, I would like to move out of this neighborhood or area
  - Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
  - Prefer not to say

5. **To your knowledge, has the state you live in ever been affected in any way by any of the following industries activities?**
   [randomize items, check all that apply]
   - Fossil-fuel based energy industries
   - Renewable energy industries
   - Heavy industries (e.g., steel, automobile, manufacturing)
   - Chemical industry

     Yes /No

6. **Have you ever heard of Carbon Capture and Storage or CCS?**
   - No, I have not heard about it
   - Yes, I have heard a little about it
   - Yes, I have heard a lot about it

CCS Factorial Survey Experiment

Section 2

You may not have heard much about Carbon Capture and Storage (CCS), or you may not agree with CCS as way to deal with CO_2 emissions and climate change. But if CCS were to be implemented in [your country], you may still have different opinions as to how CCS should be used.
In the following, we will present you with a small number of alternative CCS proposals for what a scale- up of CCS facilities on your country may look like. Carefully read each scenario and rate it based on how acceptable or unacceptable it seems to you.

Although the scenarios we show you are hypothetical, your responses and the results from this section will be used to guide policy makers in [your country] in determining CCS strategies as part of achieving [your country's] emissions reduction goals."

Example Evaluation Question: [Show picture of the final format]

Given the assumptions stated before, how acceptable is this CCS development scenario to you?

Completely unacceptable				Neither acceptable nor unacceptable						Completely acceptable
-5	-4	-3	-2	-1	0	1	2	3	4	5

1) **How fair is the proposed CO2 storage scenario to you?**
2) **How fair is the proposed storage of CO_2 from domestic and if applicable imported emissions to you?**

Completely unfair				Neither fair nor unfair						Completely fair
-5	-4	-3	-2	-1	0	1	2	3	4	5

3) **How fair is the proposed CO2 storage scenario to you?**
4) **How fair is the proposed storage of CO_2 from domestic and if applicable imported emissions to you?**

Completely unfair				Neither fair nor unfair						Completely fair
-5	-4	-3	-2	-1	0	1	2	3	4	5

Completely Acceptable / Fair means the scenario is 100% acceptable / fair to you.

Completely Unacceptable / Unfair means the scenario is 100% unacceptable / unfair to you.

[Information to be presented with Vignette intro, before first vignette rating]

You may find the following definitions useful
[presented to participants before entering vignette experiment]

Carbon capture and storage (CCS) refers to a set of technologies aimed at capturing, transporting, and permanent storage of carbon dioxide (CO_2) from different emission sources in deep underground reservoirs.

“On Demand” Definitions

Climate Change

Global warming is one of the greatest environmental challenges facing the world today. Increase in the global emissions of greenhouse gases, such as CO_2, is among the main contributory factors to climate change.

How does CCS actually work?

Some scientific studies promote CCS as a solution to climate change, as it can significantly reduce CO_2 emissions. Other studies emphasize that CCS is a costly technology and that we need to investigate its environmental and human health risks, including from induced seismicity and the leakage of CO_2 over time. Political discussions of how to best regulate and monitor the safe operation of CCS are currently ongoing.

How is CO_2 captured?

Depending on the specific application, CO_2 from the flue gases of industrial or energy-related activities are separated and captured.

How is the captured carbon dioxide transported?

Unless the source of emissions is directly located above a suitable geological storage site, captured CO_2 must be transported from the point of capture to a storage site. While pipelines are the most common method for transporting CO_2 transport by ship, road, or rail are feasible options.

Where can the CO2 be stored?

Several types of deep underground geological formations have received extensive consideration for the geological storage of CO_2: i.e., depleted oil and gas reservoirs, deep saline formations, coal beds unsuitable for mining. In each case, the geological storage of CO_2 is accomplished by injecting CO_2 under pressure into a rock formation below the earth’s surface

[For vignette sample design –> see CCS vignette xlsx file]

Attribute	Levels	
Location of CCS plant	• Less then 50 km (from residence) • Between 50 to 100 km • More than 100 km	NIMBY
Anticipated CC-mitigative benefit	• The plant's annual capacity is equivalent to the emissions of 5% of all households in your state. • The plant's annual capacity is equivalent to the emissions of 10% of all households in your state. • The plant's annual capacity is equivalent to the emissions of 20% of all households in your state.	CC mitigative benefit

Source of CO2 emissions	• It will store only CO2 from domestic sources. No CO2 imports from other countries will take place. • It will store CO2 from domestic sources and CO2 imported form the Netherlands. • It will store CO2 from domestic sources and CO2 imported form the UK. • It will store CO2 from domestic sources and CO2 imported from Norway. • It will store CO2 from domestic sources and CO2 imported from Canada. • It will store CO2 from domestic sources and CO2 imported from Germany. **NOTE:** When DOMESTIC = Source of IMPORTS. Then replace attribute level with: • CANADA: "It will store domestic emissions and CO2 imported from the USA." • GERMANY, NETHERLANDS, NORWAY, or UK: "It will store domestic emissions and CO2 imported from POLAND."	Global Justice Psychological Distance
Project oversight, execution	• Your national government oversees the building of a carbon capture and storage CCS) plant • An industry consortium plans to build a carbon capture and storage CCS) plant • A government-industry partnership has been commissioned to build a carbon capture and storage CCS) plant.	Institutional trust
Consultation process	• Citizens like yourself will not be consulted as part of the regulatory approval process. • Citizens like yourself will not be consulted but relevant NGOs will be involved in the regulatory approval process. • Citizens of directly affected community will be consulted as part of regulatory approval process. • Citizens of directly affected and surrounding communities will be consulted as part of the regulatory approval process. • All citizens in your state will be consulted as part of the regulatory approval process. • A national consultation will take place as part of the regulatory approval process.	Participatory Justice

Public access to info	• Citizens like yourself will not receive any information about the CCS plant's seismicity risk assessment. • Information about the CCS plant's seismicity risk assessment is made available online at the regulatory approval stage. • Updated information about the CCS plant's seismicity risk assessment is made available online as long as the plant operates.	Transparency, trust
Compensation, economic benefit	• The CCS plant operator does not provide any financial compensation to the host community. • Businesses in the host community will receive preferential access to construction contracts. • Citizens in the host community will receive direct financial compensation from the CCS plant operator.	Compensation, fairness

Example Vignette Scenario (using above design):

"A <u>government-industry partnership</u> has been commissioned to build a carbon capture and storage (CCS) facility <u>between 50 to 100 km</u> of your place of residence. The CCS plant's capacity is equivalent to the annual emissions of <u>5% of all households</u> in your state and will store CO2 <u>from domestic and "Dutch" sources</u>. <u>All citizens in your state</u> will be consulted as part of regulatory approval process. Citizens <u>will not receive any information</u> on the seismicity risk assessment. <u>Businesses in the host communities will receive preferential access to construction contracts</u>."

<u>Social Norms Nudging Test</u>

[Additional Vignette (#x), fixed across all N]

"Survey evidence from another study in [your country] indicates that <u>xx%</u> of the population voted in favour of the following CCS scenario."

Control group 1 (n=100) NO "survey evidence nudge" before being asked to evaluate additional scenario
Group 2 to 9 (n=125 each) YES "survey evidence nudge" at **<u>xx%</u>** rates between 10% (group 2 to 80% (group 10) before being asked to evaluate additional scenario.

"An <u>industry consortium</u> has been commissioned to build a carbon capture and storage (CCS) facility <u>less than 50 km</u> of your place of residence. The project's capacity will be used to store CO2 <u>from domestic sources</u> equivalent to <u>5% of the emissions</u> generated in your state. Citizens will not be directly consulted as part of regulatory approval process. Citizens will receive information (e.g., online portal) about the seismicity risk assessment data at the approval stage. No financial compensation to the host communities will be provided by the CCS facility operator."

How acceptable is the above scenario to you?

Completely unacceptable				Neither acceptable nor unacceptable						Completely acceptable
-5	-4	-3	-2	-1	0	1	2	3	4	5

Completely unacceptable				Neither acceptable nor unacceptable						Completely acceptable
-5	-4	-3	-2	-1	0	1	2	3	4	5

Section 3
We will now ask for your opinions about environmental issues affecting [your country].

7. **How serious do you think the following issues are facing your country?**
   [randomize items]
   - Climate change
   - Crime and violence
   - Economic stability
   - Political stability
   - Social equality
   - Energy security
   - Environmental degradation

   Extremely serious
   Somewhat serious
   Neutral
   Somewhat not serious
   Not at all serious
   Prefer not to say

8. **How much do you agree with the following statements about the role of nature and the environment?**
   [randomize items]
   - I would be willing to accept cuts in my standards of living, if it helped to protect the climate

- I would be willing to pay higher prices for goods and services, if it helped to protect the environment
- I would be willing to support higher taxes if it helped to protect the environment
- I am willing to practise sustainable behaviour if I knew I was leaving a better planet for future generations of my loved ones
- I would be willing to accept technical solutions, such as CCS, and their related risks to mitigate climate change

Strongly agree
Somewhat agree
Neither agree nor disagree
Somewhat disagree
Strongly disagree
Prefer not to say

9. **There is increasing discussion about climate change and its potential impacts. How much do you agree with the following statements about climate change?**
[Please select one response]
    - Climate change is occurring, and it is caused mostly by natural changes in the environment
    - Climate change is occurring, and it is caused mostly by human activities
    - Climate change is occurring, and it is caused more or less equally by natural changes in the environment and human activities
    - Climate change is not occurring

[Q9 if answer 4. Proceed to Q11]

10. **Please indicate the extent to which you agree with the following statements.**
[randomize items]
    - I feel a personal responsibility for global warming
    - It feels good to me to act in a climate smart way
    - I have a moral obligation to buy climate friendly products when shopping
    - Climate change is the most serious environmental problem in "my country"
    - My state is likely to be affected by climate change.

Strongly agree
Somewhat agree
Neither agree nor disagree
Somewhat disagree
Strongly disagree
Prefer not to say

Section 4
In this section, we are interested in learning more about your views and knowledge of different technologies for reducing greenhouse gas emissions and their impacts.

11. **Before today, how much if anything, would you say that you know about the following low carbon technologies?**
[randomize items]
    - Solar power
    - Wind power
    - Geothermal power
    - Biomass
    - Hydropower
    - Energy-conserving electric appliances
    - Low emission vehicles (e.g., Electric, Hybrid, Hydrogen powered)
    - Carbon Capture and Storage (CCS)
    - Carbon sequestration though forestry or agriculture

I know a great deal
I know a fair amount
I know just a little
Heard about it but really do not know anything
Never heard about it

Q12 (BWS design)

12. **Worldwide, governments have been increasing their efforts to transition away from fossil energy sources. Suppose your national government were to consider different climate policy approaches. Which type of policy approach would you find most acceptable? Which approach would you find least acceptable? Please indicate your most and least acceptable choice below.**

[randomize list]

Most Acceptable *(Choose one)*	***Policy Approach***	***Least Acceptable*** *(Choose one)*
	Put a price on CO_2 emissions (price)	
	End fossil fuel subsidies (*endsub*)	
	Increase share of renewable energy (solar, wind, biomass, hydropower) (*renew*)	
	Nurture forest landscapes (*forest*)	
	Deploy carbon capture and storage technology (*techno*)	
	Force households to adapt energy efficiency measures for home heating and electricity consumption (*househo*)	

	Enforce reductions in personal vehicle transport to encourage public transportation (*reduct*)	
	Do Nothing [ANCHOR]	

[Implementation of BWS design in Q12 using Balanced Incomplete Block Design (BIBD): BIBD for 7 items in 7 blocks each time with 4 items]

Q1

Best Items Worst

[ ] EndSub [ ]

[ ] Renew [ ]

[ ] forest [ ]

[ ] reduct [ ]

Q2

Best Items Worst

[ ] Price [ ]

[ ] Renew [ ]

[ ] forest [ ]

[ ] househo [ ]

Q3

Best Items Worst

[ ] Price [ ]

[ ] EndSub [ ]

[ ] Renew [ ]

[ ] techno [ ]

Q4

Best Items Worst

[ ] Price [ ]

[ ] forest [ ]

[ ] techno [ ]

[ ] reduct [ ]

Q5

Best Items Worst

[ ] EndSub [ ]

[ ] forest [ ]

[ ] techno [ ]

[ ] househo [ ]

Q6

Best Items Worst

[ ] Renew [ ]

[ ] techno [ ]

[ ] househo [ ]

[ ] reduct [ ]

Q7

Best Items Worst

[ ] Price [ ]

[ ] EndSub [ ]

[ ] househo [ ]

[ ] reduct [ ]

13. **We are especially interested in your level of familiarity with Carbon Capture and Storage. Please read the following statements carefully. Then indicate whether you believe each statement to be True or False.**
[randomize items]
- CCS technologies can capture more than 90 percent of CO_2 emissions from individual emitting facilities.
- CCS is viewed as the only practical way to achieve an effective decarbonization of the industrial sector.
- CCS storage of CO_2 occurs deep under the surface, well below groundwater aquifers.
- A significant leak of CO_2 to the atmosphere from a depth of more than one kilometer is almost impossible.
- CCS will always cause earthquakes, which will always be felt by humans at the surface.
- CCS is likely to cause water contamination of groundwater aquifers.

Section 5
We will now ask you a series of questions about your perceptions of different risks and Carbon Capture and Storage in more detail.

14. **In general, how willing are you to take risks?**
Very willing to do so
Willing to do so
Neutral
Unwilling to do so
Completely unwilling to do so
Prefer not to say

15. **How would you rate the severity of the following environmental health risks to [Canadians, Dutch, Germans, Norwegians, Britons?**
[randomize items]
- Climate change
- The use of Glyphosate (pesticides) in agriculture
- Living near mobile phone towers
- Living near wind turbines
- Bacteria resistant against antibiotics
- Diseases carried by insects
- Crime and violence in your country
- Illegal drugs
- Loss of the ozone layer

- Induced earthquakes caused by storing CO2 underground

    High
    Moderate
    Low
    None existing

16. **New technologies for reducing CO2 emissions such CCS, which seeks to permanently store CO_2 emissions deep underground, may have a number of associated benefits and risks. Some of these are currently still uncertain. To what extent do you agree with the following statements regarding CCS?**

    [randomize order and items for B=benefit, R=risk]

    - Has a negative impact on the environment (R)
    - Likely causes earthquakes (R)
    - CO_2 leakage out of underground CCS reservoirs contributes to future climate change (R)
    - Has a negative impact on my safety from the risk of accidents during the CO2 storage process (R)
    - Entails benefits for society (B)
    - Lowers the drive to cut carbon emissions (R)
    - Is driven more by profit than by the public interest (R)
    - Storing CO2 underground only deals with the symptoms and not the causes of emissions (B)
    - Help decrease CO2 emissions and mitigate climate change (B)
    - Is cheaper option than forcing a reduction in the consumption of fossil fuels (B)
    - Slows climate change down faster than by simply cutting greenhouse gas emissions (B)
    - Leads to an increase in economic growth in my country (B)

    Very much
    Somewhat
    Very Little
    Not at All
    Prefer not to say

17. **In general, to what extent do you support policies to scale up the use of Carbon Capture and Storage in [your country]?**

    [present on same screen with Q16]

    Strongly support
    Somewhat support
    Neither support nor oppose
    Somewhat oppose
    Strongly oppose

Prefer not to say

18. **To what extent do you accept the underground storage of CO2 in [your country]?** [present on same screen with Q16]

Perfectly Acceptable
Acceptable
Neutral
Unacceptable
Totally unacceptable
Prefer not to say

Section 6
Next, we want to know more about your thoughts on different organizations that might be involved in further developing Carbon Capture and Storage in [your country].

19. **Government and industry groups in [your country] are already considering Carbon Capture and Storage as a viable technology to mitigate climate change. When it comes to the development and implementation of CCS, please evaluate the following stake-holders in terms of their trustworthiness, responsibility, and transparency.** [randomize order]

A)

I would trust this organization to have quite a lot of knowledge about and experience with issues concerning Carbon Capture and Storage.”	
Domestic energy companies	Choose an item.
Multinational energy companies in [your country]	Choose an item.
The national governmental energy regulator in [your country]	Choose an item.
Your state-level government	Choose an item.
Politicians specializing in energy issues in [your country]	Choose an item.
Environmental organizations in [your country]	Choose an item.
Specialized independent oversight bodies in [your country]	Choose an item.
Publicly funded research organizations & Universities in [your country]	Choose an item.

B)

“I think this organization tells you the whole truth about issues concerning Carbon Capture and Storage technology.”	
Domestic energy companies	Choose an item.

Multinational energy companies in [your country]	Choose an item.
The national governmental energy regulator in [your country]	Choose an item.
Your state-level government	Choose an item.
Politicians specializing in energy issues in [your country]	Choose an item.
Environmental organizations in [your country]	Choose an item.
Specialized independent oversight bodies in [your country]	Choose an item.
Publicly funded research organizations & Universities in [your country]	Choose an item.

20. **In your opinion, which institutions or organizations should be responsible and liable for ensuring the safety of storing CO_2 emissions underground in [your country]? Please assign up to three organizations to each of the below areas of responsibility.**

	Evaluation of site-specific underground conditions for storing CO_2 long term	**Monitoring of CO2 leakage during operation**	**Monitoring of seismicity risk during operation**	**Overall safety of individual CCS projects**
CCS facility operators				
Your national governmental energy regulator				
Your state-level government				
Environmental organizations				
Politicians specializing in energy issues in [your country]				
Publicly funded research organizations & Universities in [your country]				

Taxpayers in [your country]				
Specialized independent oversight bodies in [your country]				

21. **The ultimate success of CCS depends on the proper management of its risks and benefits. In your opinion, which of the following risk issues in the management and operation of CCS are you most and least concerned about?**

[Respondents first select BW items in each of there categories. THEN generate TOP 3 and BOTTOM 3 tables (see step b), present to respondent and ask for overall TOP and overall BOTTOM choice.]

a) **For each of the following three categories, please indicate the issues of greatest concern and the issue of least concern to you.**

Most Acceptable *(Choose one)*	**Government and Industry Factors**	***Least Acceptable*** *(Choose one)*
	Competent regulatory oversight of CO_2 storage site selection	
	Adequate risk assessment and risk management of CCS	
	Supportive public policy for CCS as part of a climate change plan	
	CCS operator financial liability beyond the facility operation period	
	Do Nothing [ANCHOR]	

Most Acceptable *(Choose one)*	**Environmental Risk Factors**	***Least Acceptable*** *(Choose one)*
	Adequate scientific study of CO_2 storage site underground conditions	
	Effective mitigation of groundwater contamination due to induced seismicity	
	Credible long-term monitoring for leakage at CO2 storage sites	
	Independent monitoring of CCS sites for seismicity risks	
	Do Nothing [ANCHOR]	

Most Acceptable (Choose one)	**Socio-economic Factors**	*Least Acceptable (Choose one)*
	Independent evaluation of economic costs and benefits of CO_2 storage projects before construction	
	Mandatory consultation of affected communities in the CCS development process	
	Clear rules for transparency and accountability in CCS approval and monitoring processes	
	Use cost-sharing between government and industry to move CCS technology forward	
	Do Nothing [ANCHOR]	

b) Now, please select <u>the</u> one issue you are the most concerned and the issue you are the least concerned about when it comes to the management of CCS.

Most Acceptable Items	**Choose one**
Top Government and Industry Factor	
Top Environmental Risk Factor	
Top Socio-economic Factor	

Least Acceptable Items	**Choose one**
Bottom Government and Industry Factor	
Bottom Environmental Risk Factor	
Bottom Socio-economic Factor	

22. **In your opinion, what should be a minimum acceptable level of monitoring of CO2 storage facilities to assure their safe operation.**
[check one]
    - Mandatory monitoring of CCS seismicity risks over the course of the operation of the facility.
    - Mandatory monitoring that helps to understand likelihood & severity of CCS seismicity risks over the course of the operation of the facility.
    - Mandatory monitoring that is able to forecast likelihood & severity of CCS seismicity risks over the course of the operation of the facility.
    - Mandatory monitoring that is able to mitigate likelihood & severity of CCS seismicity risks over the course of the operation of the facility.

Section 7

This is the final section we will ask you a few questions about yourself. This demographic information helps us know that we have collected a broad range of perspectives from citizens in [your country].

23. **Do you or have you or a close relative worked in any of the following?**
[check all that apply]
    - Energy industry or related government department
    - Heavy industry or related government department
    - Chemical industry or related government department
    - Environmental organization
    - None of the above
    - Prefer not to say

24. **Please indicate your gender.**
    - Female
    - Male
    - Other
    - Prefer not to say

25. **What is your highest educational attainment?**
    - High school
    - College
    - Undergraduate degree
    - Graduate degree
    - Technical or trade certificate
    - Prefer not to say

26. **What is the total number of individuals living in your household, including children?**

____

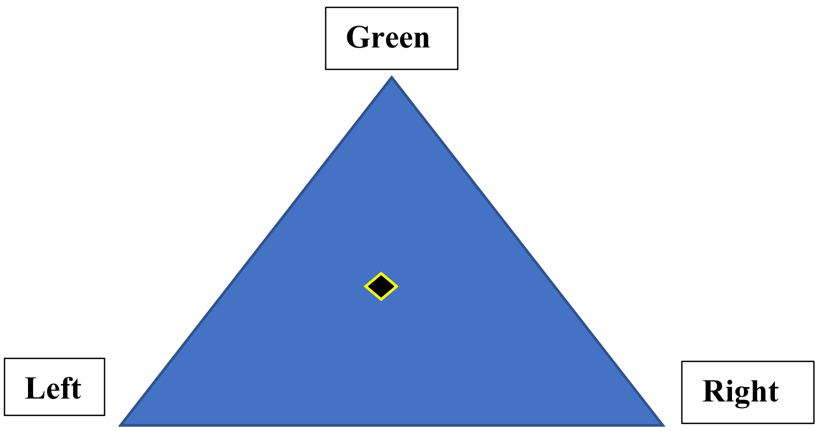
27. **What is your approximate gross annual household income? _______________**
[If no answer, ask brackets version]

28. **What is your gross annual household income?**
    - Less than $20,000
    - $20,000 - $39,999
    - $40,000 - $59,999
    - $60,000 - $74,999
    - $75,000 - $99,999
    - $100,000 - $149,999
    - More than $150,000

- Do not know
- Prefer not to say

29. **What is your postal code, please __________**

30. **Please describe your political view. Use the cursor within the border of the below triangle to indicate your general political views between social democratic (left), conservative (right), and green (environmentally inclined) positions.**



31. **Do you have any comment or questions for us?**

...

This completes our survey. Thank you very much for your time and participation in our survey. Your input is greatly appreciated. We would like to remind you that your data is completely confidential. After you press the submission button below, you will not be able to withdraw from the study.

SUBMIT & COMPLETE

1. STAGE OF STUDY