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Consumer Attitudes towards Industrial CO_2 Capture and Storage Products and Technologies

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Abstract: This paper discusses and elicits consumer attitudes towards industrial carbon dioxide (CO_2) capture and storage (ICCS) products and technologies. It presents a comprehensive review of the relevant research literature on consumer attitudes towards ICCS represented by the willingness-to-pay (WTP) and willingness-to-accept (WTA) negative externalities and outcomes of the carbon capture and storage (the so-called "not-in-my-backyard" (NIMBY) approach). In addition, it employs a concise empirical model that uses the data from the online questionnaire survey conducted in 7 European Union (EU) countries with and without ICSS sites. Our results demonstrate that having at least one ICCS site significantly reduces the WTA for the ICCS products and technologies. It is shown that further increase of ICCS sites, including those in the neighboring regions and countries, leads to the increase of negative consumer attitudes to the ICCS technologies and renewable energy policies. It becomes apparent that the majority of consumers are willing to support industrial CO_2 capture and storage only if it happens far away from their dwellings. The outcomes of this paper might be informative for the EU local industries and policy-makers who are planning the location of ICCS sites and optimizing the public support for their endeavors. Moreover, they might be relevant for the stakeholders dealing with the threat of climate change and the necessity for the decarbonization of the economy.

Keywords: carbon capture and storage; energy efficiency; CO_2 emissions; consumer attitudes; sustainable technologies; energy and power

1. Introduction

According to the World Bank [1], the post-World War II (WWII) era is marked by a global economic upturn, which was characterized by growth in the global populations, industrialization, and unprecedented utilization of resources driven by decolonization and globalization. However, the emergence of industrialization as a main economic growth driver globally, harbingered other concerns for the global community because the carbon dioxide (CO_2) emissions from the industries and the utilization of the resources were proving to be a source of environmental pollution and severe global warming based on the evidence from the United States (U.S.) and the European Union (EU) [2] alike. According to the U.S. Department of Energy [3], the manufacturing sector, including cement plants, chemical plants, refineries, paper mills, and other manufacturing facilities, contribute on average, more than 25 percent of CO_2 emissions, the equivalent of 5.5 million metric tons of CO_2 emissions. The American Recovery and Reinvestment Act of 2009 gave the National Energy Library an opportunity to explore various alternatives that could be used to reduce or manage CO_2 emissions from the manufacturing sector, which led to the pursuit of industrial carbon capture and storage (ICCS) as technology that can be utilized to achieve these objectives [4]. However, the ICCS technology has been in use for a long time now but the U.S. government, working with other stakeholders, is evaluating different methodologies of implementing the same across the economy to mitigate the CO_2 emissions.

Consequently, various initiatives have been rolled out over the years to ensure that the CO_2 emissions are not harmful to the environment or are put to better use. One of these approaches are the industrial carbon capture and storage (ICCS) technologies which facilitate the decarbonization of the manufacturing and other sectors of the economy that contribute to the increase of the global CO_2 emissions. With regard to the above, Reiner [5] points out that CCS technologies might constitute an essential route to meet climate mitigation targets in the power and industrial sectors. The ICCS process is aimed at ensuring that the CO_2 emissions, which have been growing at a rate commensurate with the industrialization and globalization levels, are minimized in order to utilize the available renewable and non-renewable sources of energy sustainably and protect the environment [6]. According to some estimates, widespread deployment of carbon capture and storage could account for up to 1/5 of the needed global reduction in CO_2 emissions by 2050 [7]. ICCS puts the CSS at the industrial level. ICCS represents a set of technological processes that includes the following components:

- capture of CO_2 at fossil power plants or other industrial sites with high CO_2 emissions,
- transport of the captured CO_2 via pipelines or ships to appropriated storage sites,
- permanent storage of the CO_2 in storage sites,
- monitoring the stored CO_2 for a very long period of time.

One would probably agree with us that ICCS technologies represent a very effective means of decarbonizing energy-intensive industries today, including the steel, cement, refineries, as well as chemical industries which have reached to the maximum theoretical efficiency. Nowadays, in the EU, industrial CO_2 emissions are dominated by iron and steel production (19%), chemicals industry (15%), petroleum refining (14%) and cement/lime production (11%) [8]. Moreover, ICCS deals with a variety of procedures whereby the emissions are captured at the source of production, and they are transported through the most suitable means such as pipeline and finally stored on a permanent basis [9]. However, ICCS technologies also consume large amounts of energy and lead to a loss of efficiency: the reduction of the emitted CO_2 amounts to a maximum of 65–90% provided that the storage is secure and permanent [10].

This paper explores and studies the general feeling that the consumers have towards all the highlighted issues concerning ICCS and the challenges that are posed towards meeting the satisfaction of the consumers, especially those that one would encounter in the 21st century that is marked by innovation and technological progress. The threat of global warming that is becoming irreversible and dangerous for the further development of human civilization, calls for the global and viable decarbonizing solutions that ICCS technology presents despite all its shortcomings. The new energy balance for the 21st century is likely to include large CSS plants, either state-owned of private deployed across various locations around many countries. We argue that understanding the potentials of this technology and its importance for the energy and power sectors should be communicated to citizens and presented as a favorable outcome backed up by the transparent data and success stories.

2. Overview of ICCS Main Characteristics

2.1. ICCS Trends and Challenges

One of the primary procedures that is used today by industries with the aim of reducing the amount of CO_2 in the atmosphere is by capturing the gas and sequestration of CO_2. This process has been greatly appreciated by the consumers as it has worked out perfectly. This is because the CO_2 gas is permanently stored in the underground facilities where it is impossible for it to come out and to be released into the atmosphere [11]. The process starts by the CO_2 capture from the power plants and industries. Then it is compressed and transported through pipelines whereby it is then injected into deep underground rock formations. The porous rocks are the ones that hold the gas, and it is worth noting that the gas is injected to the underground in the distance more than a mile beneath the surface of the ground. Non-porous layers of rocks also trap the gas, and it is held permanently, and chances of the gas going to the atmosphere are very minimal. This method received a widely acclaimed support from many stakeholders as it is very effective [12–14].

In countries, such as the U.S., for example, more than 40% of the total emissions of CO_2 come from electric power generation. ICCS has played a critical role in the aim of reducing the overall effects of the greenhouse gas emissions (i.e., emissions of all harmful substances contributing to the greenhouse effect of which CO_2 is arguably the worst). By this, there has been the production of low-carbon electricity generation from power plants. It is essential to highlight that in the U.S. the ICCS has enabled the total emissions of the CO_2 to the atmosphere to be reduced by about 80% and therefore many people are very positive towards the use of the ICCS due to the huge success and the overall achievements of this technological advancement [15].

The Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) have all highlighted the need to control the global greenhouse gas emissions (see the point above) [16]. In the past years, the reduction of the emission of the gas have been based on factors such as the enhancing energy production and increasing renewable energy production but there have been challenges facing these kinds of, measures and it is worth noting that these measures also proved to be very costly. As a result of these challenges, the alternative and most suitable approach that would also otherwise be less costly and applicable is the ICCS [17–19].

There are questions raised about whether there is a need to reduce CO_2 emissions to the atmosphere. Emissions of the gas to the atmosphere tend to increase the average global temperature. Of all the greenhouse emissions, CO_2 is the most abundant as it represents the gas that has the most adverse effects and results on the global warming. As the global warming becomes more severe and the climatic patterns experience significant changes, scientists are starting to raise alarms about the survival of our natural environment [20].

From previous research conducted by various authors and institutions, it has been noted that the general public does not put matters regarding the environment and global warming as its main priority or interest. The environment is therefore not a pressing concern to the majority of the public, and as a result, even among those few who are concerned about the environment, they are not entirely concerned about the effects of global warming. It appears that the vast majority of people has not heard about the ICCS and are also least concerned as to what it entails [21]. From these research and studies, it, therefore, becomes an issue of concern as there are great challenges that are posed to the environment especially when it comes to the realization that many people are less concerned with environmental issues. When people are explained to about the effects of greenhouse gasses such as CO_2 to the atmosphere and the general idea of ICCS, a majority of people seems to support the idea. In some countries like China that are quickly adapting the trend of CSS technologies, the acceptance of CO_2 emissions and the deployment are perceived by the general public as the contributions to the positive image of the sustainable development [22].

Today, there are about sixteen completed and fully established ICCS plants, and two of these are in power plants globally [8]. There are many challenges that face as far as the success of ICCS is concerned. It is critical to note that of all the established ICCS today, governments of the respective nations that the ICCS are established are always involved so as to aid in the cost of the manufacture and the care. This tells that there are high costs involved in the establishment of this ICCS. As a result, the private sector is not willing to engage itself in this matter especially in the EU. The prices of carbon in the EU are also a factor to consider. Until the prices of carbon go high, then that will be the time that the private sector will fully embrace the idea of ICCS. The governments of different nations cannot, therefore, be able to fully establish these ICCs without the full support of the private sector.

As stated above, one of the main activities that lead to the emission of CO_2 to the atmosphere is power plants as well as burning of fossils. Therefore, there has been a heated argument on which are the countries that will benefit more from ICCS. Countries that produce coal and gas are set to benefit more than other countries that do not produce the two. Developed countries such as Australia, the U.S. and most the EU Member States also have a comparative advantage (as compared to, for instance, the developing countries in regions such as Asia and Africa) because the economically developed countries have enough resources to cater for the establishment of the costly ICCS technologies [23–28]. Moreover, Rodrigues et al. [29–31] show that in addition they follow the plan of reducing greenhouse gases through using advanced technologies that allow to eliminate CO_2.

Policies in the EU are also vital for the establishment of the ICCS in order to contribute to the decarbonization of local economies [32]. The European Parliament and the Council of Europe are in accord that the 15% CO_2 reduction in the EU that it committed to being accomplished by 2030, can be achieved by the use of ICCS [33].

The ICCS policy approaches and choices depend on funding, costs and risks, subsidies, and technology support [34–36]. For the funding, it will greatly depend on how incentives and capital will be deployed for the ICCS to succeed over the coming years. The costs and the risks will be determined especially based on the people who will bear these costs whether the public or the private sector are concerned, as well as on the view of relevant stakeholders [37–40]. For every intended development to succeed, there must be costs and risks to be incurred, and certainly, there are those who suffer and carry the burden of these costs.

Policies related to ICCS will also be based on the abatement of subsidies and together with penalties laid down for those who will be found with the offense of releasing emissions to the atmosphere. The importance of this is to ensure that industries and power plants will find it necessary to establish ICCS to avoid these penalties [41]. Advanced and cheaper technology is important so as to reduce the overall cost of the establishment of ICCS. When these policies become effective especially in the European Union, then the attitude of the consumers towards the ICCS will be very positive, even though, according to some researchers, this might differ for some countries (e.g., Germany) due to various factors [42].

2.2. Stakeholders' Attitudes towards ICCS

With the growth of the manufacturing and production sector, ensuing from a growth in industrialization, there has been an increasing threat of global warming and depletion of resources. Consequently, it has become imperative for various stakeholders to come together and formulate and implement various initiatives that foster green and sustainable manufacturing and production. In addition, with the increased levels of awareness about the impending threats of climate change created by the mass media, customers and the society, in general, has increased the levels of environmental stewardship, which has furthered the environmental stewardship agenda.

More specifically, Solomon et al. [43] argued that the increased levels of CO_2 emissions across the globe caused by the utilization of fossil fuels to power the industrialization strategies are contributing to the depletion of the ozone layer and leading to various environmental issues such as global warming, which cause irreversible environmental damages. They further demonstrated that the environmental changes occasioned by the current emissions could have a negative impact on the environment up to 1000 years after the emissions stop. In agreement, Tol [44] observed that the growth in the levels of CO_2 emissions has various associated explicit and hidden costs, which have a negative impact on the environment. Evidently, if the global CO_2 emissions rates were to progress unfettered or unmanaged, there is a higher risk of experiencing environmental changes, which could be detrimental to the environment and the well-being of the populace.

According to the Global CCS Institute [8], the industrial carbon capture and storage technology have been in application for decades now and a hub and cluster network of the various organization have come together to utilize the technology to manage their CO_2 emissions. The report by the same institute established that whereas point-to-point projects or independent projects could be costly, the cluster and network approach enables multiple organizations to come together and utilize the technology to manage their CO_2 emissions. The cluster and network approach facilitates smaller industrial facilities to pool together and reduce the risks and costs associated with the use of the ICCS technology. This trend which means that various companies come together to work towards the implementation of the ICCS technology, indicates that many organizations are ready and willing to cooperate to adopt and implement the technology in a joint effort to manage their CO_2 emissions, and play an environmental stewardship role.

The U.S. Department of Energy [3] provides an example of various organizations that are involved in the tests and implementation of the ICCS technology on various levels to facilitate the management of CO_2 emissions. For example, Air Products & Chemicals, Inc. (Allentown, PA, USA) is working together with Denbury Onshore, LLC (Plano, TX, USA), Archer Daniels Midland Company (Chicago, IL, USA), and Leucadia Energy, LLC (Salt Lake City, UT, USA), which are working with the department of energy to capture and store CO_2 for more beneficial utilization of the CO_2. Manufacturing companies, in pursuit of sustainable productivity, have demonstrated a positive attitude towards the implementation of various initiatives aimed at improving the level of environmental stewardship, because these firms draw their resources from the environment.

The implementation of various initiatives around ICCS management carried out by manufacturing companies as well as the increased pressure from the government, the international community, and consumers, has increased pressure on the players in the value chain who participate in these initiatives to foster the management of CO_2 emissions [45]. Quite often, ICCS represent a challenging and sensitive issue, especially on the new CSS deployment sites, such as for example China [46,47]. Consequently, business partners of the manufacturing partners such as distributors and large-scale retail chains have also implemented various initiatives that support the overall CO_2 emissions reduction and management. The end-to-end stakeholders' involvement approach ensures that there is a holistic management of CO_2 emissions across the value chain [48].

For example, distributors of products from manufacturing companies such as the Coca-Cola are also participating in various initiatives, such as the purchase of low-CO_2 emissions vehicles, recycling and reuse of plastic packaging materials, and other initiatives that facilitate the achievement of the global CO_2 emissions management and reduction agenda [49]. Further, such a strategy will cover supply chain partner firms such as transport and logistics companies, which have also implemented initiatives to ensure proper environmental management strategies are implemented across the value chain. In addition, resellers such as supermarkets have adopted various green and sustainable reselling approaches including giving prominence to products from companies that have implemented strategies that help to deal with the CO_2 emissions [50].

However, Lubin and Esty [49] observed that the costs associated with such initiatives could be a hindering factor for various entities in an economy to adopt and implement CO_2 emissions management initiatives but argued that the overall direct and indirect benefits will be valuable to any entity in the long-term. From this, it is evident that the costs associated with the implementation of either ICCS and or any other CO_2 emissions management and reduction initiative could cause an entity to have a negative attitude towards such an initiative. The overall benefits and the contribution to the achievement of organizational, national, and the global community's goals and objectives is a mitigating factor. Therefore, regardless of the negative implications of the costs in the short-term, it is important for an organization across the value chain to implement ICCS or any other initiative that will contribute to the management of CO_2 emissions.

2.3. Consumer's Attitudes towards ICCS

In a value chain, the end consumer is the last entity; they are the people or the entities that are the users of the products goods, or services, produced by a firm.

In the 21st century, the consumers are more knowledgeable and demanding. In addition, they are more educated and have immediate access to diverse information from various sources which is enabled by the widespread use of Internet and social networks [51]. With the increased levels of awareness created about the risks that the increased levels of CO_2 emissions could pose to the well-being of the human race and the increased levels of sensitization on the need for environmental management, one can observe that the end-consumers are increasing their levels of environmental stewardship [30]. Furthermore, at the individual level, end-consumers are making purchasing decisions based on the reputation of companies in relation to environmental management strategies, implying that early adopters in this field, are poised to enjoy increased business from the modern-day end consumer [49]. Finally, the global consumer is increasingly playing an activist role, where they actively engage each other and corporates in the manufacturing sector to agitate for increased awareness and implementation of strategies aimed at managing the CO_2 emissions from productive activities [45]. Evidently, from the foregoing, the modern-day end consumer has a positive attitude and engages in activities that foster environmental stewardship and will support initiatives such as the implementation of ICCS and other related projects that mitigate the growing CO_2 emissions.

Nevertheless, there is also a plethora of issues related to the general public and end consumers' attitudes towards ICCS technologies and their deployment. There are lots of cases where the clear explanation and communication between the stakeholders and industries and the end consumers are required. The general public needs to be made aware of all costs and benefits of the ICCS, as well as about the advantages it presents and the outcomes in terms of halting the CO_2 emissions in the short run by the large-scale application of CSS technologies. Quite often the communication goes wrong and the pros and cons are not explained correctly. For example, Broecks et al. [52] demonstrate that people find arguments about climate protection less appealing and persuasive than normative arguments or arguments about benefits of CCS for energy production and economic growth. Furthermore, Kraeusel and Möst [53] investigate the level and influencing factors of social acceptance of CCS on the example of Germany and find out that the attitude towards CCS is neutral and the level of willingness to pay for CCS technology is much lower than for renewable energy (see Table 1).

Table 1. Overview of relevant selected studies on consumer attitudes towards ICCS.

Region	Countries	Surveying Methods	Key Points and Results	Source
Europe	Netherlands	(i) Online survey; (ii) discrete choice experiment	Citizens find arguments about climate change less persuasive and/or important than other arguments (e.g., economic benefits or safety)	Broecks et al. [52]
	Sweden	Qualitative analysis with contrasting approaches: (i) transmission approach; and (ii) participatory approach	(i) ICCS communication based on different assumptions about the social framing of ICCS (e.g., the public's ability or the public's interest in helping frame ICCS); (ii) it is crucial who formulates the message of the necessity to implement ICCS	Buhr and Wibeck [54]
	Germany	(i) online survey with 130 university students in Dresden; (ii) choice experiment	Attitude towards ICCS is neutral and the level of willingness to pay for ICCS technology is much lower than for renewable energy	Kraeusel and Möst [53]
	6 EU countries	Focus groups	ICCS perceived as an uncertain, end-of-pipe technology perpetuating fossil-fuel dependence (from uncertainty to negative position)	Upham and Roberts [55]
North America	United States	(i) Phone and mail survey; (ii) regression analysis (probit)	About 80% never heard of ICCS; positive view of ICCS if respondent believes that human activities contribute to climate change, supports RES; negative view of ICCS if respondent is apolitical and conservative	Carley et al. [56]
Asia	China	(i) online questionnaires; (ii) face-to-face interviews	(i) General public is not fully aware of ICCS (compared with other renewables); (ii) attitude towards ICCS is slightly supportive (alternative technological option to mitigate climate change); (iii) public cognition, economic benefits and environmentalism exerted a positive impact; (iv) perceived risk has a negative effect on the acceptance of ICCS	Guan et al. [22]; Yang et al. [57]; Zheng and Xu [58]
Australia	Australia	Choice experiment estimating community values for climate change mitigation	Respondents who do not believe in climate change have a lower WTP for reducing Australia's CO_2 emissions	Kragt et al. [59]
Worldwide	World	Literature review of research studies, papers and policy reports	(i) People's concerns and spontaneous reactions to the ICCS form a good basis for risk communication about ICCS; (ii) the role of the context (particularly the social context) in which ICCS would be deployed deserves more research	Selma et al. [60]; Vercelli et al. [61]
	U.S., EU, and Japan	(i) Questionnaire survey (31 identical questions); (ii) follow-up questionnaire survey (7 questions)	(i) Small differences across the regions and different groups of stakeholders; (ii) all stakeholders considered reductions in emissions with current technologies severe; (iii) a view that ICCS will occupy electricity sector market within 10–20 years; (iv) regional disagreements about the climate change and the role of NGOs	Johnson et al. [62]
	China, India, Japan, EU, Russia, and U.S.	Overview and analysis of the existing literature and policy papers	(i) Main barriers for ICCS are economic and social; (ii) when the costs for emitting CO_2 are lower than those of ICCS technology, there is no market-driven development of ICCS; (iii) achieving wide public acceptance is the main challenge	Wennersten et al. [63]
	World	Bibliometric analysis of peer-reviewed published papers based on bibliographic coupling	(i) Research is dominated by technical research (69%); (ii) 31% of papers address non-technical issues with a broader view on ICCS implementation on the regional or national level or using assessment frameworks; (iii) research is attempting to meet the outlined problems, which are mainly non-technology related.	Viebahn and Chappin [64]

Moreover, it might be that the debate on ICCS technologies with the general public and end consumers should be done on the micro-level: some findings demonstrate that small-scale engagement processes might present a viable alternative to standard community consultation techniques for engagement around the siting of CCS facilities [65].

According to Wennersten et al. [63], the major barriers for implementation of ICCS on a large scale are not technical, but economic and social. The key challenge for ICCS is to gain wide public acclaim, which is likely to shape up the future political attitude to it [65]. Such an approach requires a transparent communication about safety aspects early in the planning phase and dealing with potential disasters and hazards such as major leaks of CO_2.

All in all, one might conclude that consumer attitudes towards ICCS might differ due to many reasons. Table 1 provides a comprehensive overview of selected relevant quantitative and qualitative studies on consumer attitudes towards ICCS products and technologies.

3. Research Methodology and Data Description

The empirical model outlined in this paper which is designed to test the WTA for ICCS sites is based on the individual-level survey questionnaire on the public perception of ICCS in several European Union countries. The model employs the data on the exact location of ICCS storage sites and other relevant regional characteristics.

The data for our model was obtained by the means of an own representative online survey (using a popular online surveying interface) which was conducted from January to February 2017 in seven EU countries (represented by the Czech Republic, Italy, Germany, the Netherlands, Poland, Slovakia, and the United Kingdom). The respondents were selected via an online interface using the contact points (so-called "gatekeepers") in the countries in question. The contacts and the selection of respondents was made possible using the extensive graduate student networks in the countries in question. The students in the respondents' countries were tutored in administering online questionnaires and facing possible inquiries and questions. In order to ensure the ethical norms and standards that are typical for such studies, written informed consents were obtained from all the subjects prior to the study via the simple online form.

In order to make the sample more representative, the quotas were set for such characteristics as age, gender, and the country of residence. Overall, after the data were cleared from the outliers and missing values, the final sample used for our analysis included 564 valid observations. The average age of respondents was 45 years. In total, 56% of the respondents were male, 44% were female. In total, 88% of respondents had a college degree. More than 35% of the respondents had a higher education degree (university degree or higher).

The methodology employs a regression framework that is used to analyze the effects of living in a county with an ICCS storage site on a consumer's willingness-to-accept ICCS. The model also takes into account the number of ICCS sites located in a given EU county and spillover effects from neighboring regions or counties. The model can be presented in the following form:

$$A_{i,j} = \alpha + \beta X_i + \gamma Y_j + \varepsilon_{i,j}, \quad (1)$$

where:

$A_{i,j}$ (acceptance)—dependent variable that expresses the level of ICCS acceptance of individual i who lives in county j. The variable might take the values from 1 ('strongly disagree') to 4 ('strongly agree') (i.e., Likert scale-type variable);

X_i—vector of individual socio-demographic characteristics (age, gender, education, and income);

Y_j—vector that contains different alternative indicators for the presence of ICCS sites in a given country or region.

$\varepsilon_{i,j}$—error term (residual or a disturbance term that represents the combined effect of the omitted variables that is (i) is independent of each variable included in the equation; (ii) independent across subjects; and (iii) has expectation 0).

The individual socio-demographic characteristics contained in X_i can be explained in greater detail as follows: (i) gender indicates whether individual is female; (ii) age measures the number of years of age; (iii) education indicates whether individual i has a higher education entrance certificate; and (iv) income measures the monthly household net income (calculated in euros).

In addition, the alternative indicators for the presence if ICCS contained in Y_j are represented by the dummy variables that indicate the existence of at least one ICCS sites in a given county, several sites, or ICCS sites in the neighboring countries.

4. Model Results and Discussion

This section reports the results of our empirical model and provides the discussion of its results. The model itself was developed and described in greater detail in the previous section (see Equation (1)). The main aim of the model was to test for the effects of living in a county with an ICCS plant and the WTA of such a technology in the respondent's immediate proximity.

The simple regression form of our model is based on some related and similar studies conducted for the same purpose in other countries (e.g., [51,52,54]).

Table 2 depicts the findings from the ordinary least squares (OLS) regression using three separate but closely related models: (i) model 1 uses a regression described in 1 with a dummy that indicates whether there is at least one ICCS site in a given EU country from our sample; (ii) model 2 uses a dummy that indicates whether there are several ICCS sites in the country or region (the number of countries is indicated by a variable); (iii) model 3 uses a dummy that indicates the existence of spill-over effects (ICCS sites in the neighboring regions or countries).

The OLS method was used due to its common usage as well as due to the simple fact that the ordered logit regression performed as a robustness check, yielded very similar results. This allows to justify using OLS for further estimations and outcomes.

Table 2. Ordinary least squares (OLS) regression clustered standard errors.

Willingness-to-Accept (WTP) of ICCS Sites	Model 1 [a]	Model 2	Model 3
Acceptance of ICCS site	−0.472 ** (0.264)		
Number of ICCS sites		−0.216 ** (0.046)	
ICCS sites in the neighborhood			−0.428 * (0.224)
Proximity to coal mines	−0.221 ** (0.320)		−0.971 * (0.611)
Gender	0.612 ** (0.222)	0.633 ** (0.226)	0.564 ** (0.226)
Age	0.003 (0.007)	0.002 (0.008)	0.051 (0.007)
Population density	−0.004 (0.003)	−0.003 (0.002)	−0.004 (0.003)
Level of education	−0.031 (0.022)	0.221 (0.201)	−0.667 (0.210)
Income	0.0006 (0.0008)	0.0005 (0.0005)	0.0001 (0.0008)
Constant	4.754 ** (0.446)	4.724 ** (0.465)	4.721 (0.462)
Number of observations	564	564	452
R-squared (R^2)	0.067	0.084	0.064

[a] Note: see the explanation of the models in the text above. *, **, *** denotes the significance level less than 1 percent, 5 percent, and 10 percent, respectively.

In general, it appears from the results of our model that the acceptance of ICCS declines if an individual resides in a region with at least one potential ICCS storage site (note the negative signs of the coefficients). The acceptance of ICCS is about three times higher for females than for males (the significant and positive signs of the Gender variable). Moreover, it appears that other socio-demographic characteristics seem to have no effect on the ICCS WTA. An interesting factor is the presence of coal mines in the region or country—when coal mines are present, the ICCS WTA declines. The explanation we might come up with is that this is happening due to the fact that when familiar with coal mines and the pollution they cause, consumer associate ICCS facilities with them and extrapolate their perception of coal industry to CSS, which is not always correct.

In addition, the signs and the magnitude of the coefficients show that adding one more ICCS site to a country or region negatively impacts the overall willingness-to-accept ICCS products and technologies (the reduction of about 20%). In addition, it appears that spill-over effects also play a significant role: living next to the region or a country with potential ICCS products and technologies reduces the acceptance level by 40%.

Furthermore, one needs to explain the effects of ICCS site, number of ICCS sites, and ICCS neighborhood in greater detail. First of all, it appears that the presence of ICCS sites in the respondent's immediate neighborhood appears to reduce the level of acceptance in a relatively large geographic area. Second, the larger the number of ICCS sites in the country or region, the lower is the willingness-to-accept ICCS in a given location. Finally, living in a country or region bordering another country or region with ICCS sites present, also reduces the consumers' support for accepting similar facilities in their region. It seems that NIMBY attitude prevails in all of the above cases.

5. Conclusions and Policy Implications

Overall, one would probably agree that recent climate change and ongoing global warming would inevitably call for the optimal solution that would allow meeting climate targets without compromising the use of energy resources. ICCS provides the cost-optimal and, in fact, the only possible solution to these impending issues given the state of development of human science and the technology readiness level our civilization possesses.

It is important to note that the above challenges of ICCS are similar to those that are faced by the power sectors today even though as highlighted in the discussion, the industrial applications, the high costs, and the general attitude of the private sector and the consumers are also factors that come into consideration. ICCS can be a lasting solution in the long term if only nations agree to embrace the idea, and also consider protecting the ozone layer and therefore preventing global warming through the decarbonization of the economy.

With the growth in industrialization realized so far in the global society and further projected growth moving forward, it has become important for various stakeholders to come together and implement initiatives that mitigate this trend. Consequently, there has been a lot of sensitization and creation of awareness, coupled with the formulation and implementation of laws, regulations, and policies aimed at supporting the achievement of a reduction in, and management of CO_2 emissions. Because of the increased levels of awareness, the costs incurred in managing the CO_2 emissions notwithstanding, companies, resellers, and end-consumers have a positive attitude towards these initiatives.

Nevertheless, it should be noted that the first wave of optimism about the ICCS large-scale projects between 2005 and 2009 that led to the deployment of CSS plants in Canada, United States, Australia, and Saudi Arabia has quickly subsided due to a number of technical, economic, and political reasons (e.g., high cost of capture technologies, technological uncertainties in CCS systems, as well as underdeveloped regulatory and liability regimes). In the European Union, where CO_2 transport and storage do not yet exist at the same scale as, for example, in the United States, sufficient investment incentives led by the European Commission of the governments of the single EU Member States might help to increase the deployment of ICCS facilities throughout the continent.

New incentives, perspectives as well as insights are needed in order to make the idea of ICCS plants viable and to attract the attention of the general public as well as end consumers to this issue. The current plunging oil prices put all this at risk, since many stakeholders think in terms of business and profit. There are many remaining questions about how to proceed with ICCS initiatives and how to make them attractive and profitable. Commercialization of ICCS projects (i.e., putting them into the private hands) is not viable quite yet due to the risks associated with the full functioning of all three stages of the process (capture, transport, and storage). However, it might be possible given the successful examples of Tesla's space flights program. One day, private companies might do a better job dealing with all stages of CCS similar as they do with municipal waste management in large U.S. cities.

In addition, it becomes apparent that to make large-scale deployment of ICCS economically useful and viable, a more mature CCS industry with lower unit price per t_{CO2} is needed. The process of maturing this technology is ongoing and should go hand in hand with educating the general public (most importantly citizens of the developed industrialized countries) about the importance of ICCS plants and facilities for decarbonizing the power and industry sectors.

Currently, the negative or reluctant attitude to ICCS technologies that prevails in many countries, including the developed economies of the EU, might present some threats for their further development and refinement. The results of our review and our research based on the empirical model demonstrate that consumer attitudes towards these technologies might be influenced by a plethora of factors in which behavioral ones are likely to play the key role. Therefore, we think that consumer attitudes towards industrial CO_2 capture and storage products and technologies require further investigation that should employ, for example, larger cross-country (or even cross-regional) samples of respondents, such as energy consumers, producers, as well as relevant stakeholders, for gaining a deeper understanding of this problem and finding ways for shifting the negative attitudes for achieving the positive energy balance.

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