

**Affect Matters: Going Beyond Rational Decision-Making Processes to Understand
Social Acceptance of Renewable Energy Sources**

DISSERTATION
of the University of St.Gallen,
School of Management,
Economics, Law, Social Sciences,
International Affairs and Computer Sciences,
to obtain the title of
Doctor of Philosophy in International
Affairs and Political Economy

submitted by

Julia Cousse

from

Meyrin (Geneva)

Approved on the application of

Prof. Dr. Rolf Wüstenhagen

and

Prof. Dr. Evelina Trutnevyte

Dissertation no. 5098

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The University of St.Gallen, School of Management, Economics, Law, Social Sciences, International Affairs and Computer Science, hereby consents to the printing of the present dissertation, without hereby expressing any opinion on the views herein expressed.

St.Gallen, May 20, 2021

The President:

Prof. Dr. Bernhard Ehrenzeller

*“Hence, in order to have anything like a complete theory of human rationality, we
have to understand what role emotions plays in it.”*

— **Herbert Simon (1983, p.29)**

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Geneva, March 2021

Julia Cousse

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List of Abbreviations and Symbols¹

Abbreviations

CHF	Swiss franc
COP	Conference of Parties
CO ₂	Carbon dioxide
DGE	Deep geothermal energy
ES2050	Energy Strategy 2050
GWh	Gigawatt hour
GHG	Greenhouse Gas
IAT	Implicit Association Test
IEA	International Energy Agency
km	Kilometer
NIMBY	Not in My Backyard
PIMBY	Please in My Backyard
PV	Photovoltaic
RE	Renewable energy
SFOE	Swiss Federal Office of Energy
%	Percentage

¹ Please note that relevant abbreviations are introduced within each paper.

TAF	Technology acceptance framework
UNFCCC	United Nations Framework Convention on Climate Change

Statistical Symbols and Abbreviations

Adjusted R^2	Adjusted Coefficient of determination
ANOVA	Analysis of variance
B	Unstandardized beta
β	Standardized beta
df	Degrees of freedom
F	F-Statistic
M	Arithmetic mean
IQR	Interquartile range
MED	Median split
n	Number of observations
η^2_p	Partial eta-squared (measure of strength of relationship)
p	Error probability
R^2	Coefficient of determination
SD	Standard deviation
SE	Standard error
SPSS	Statistical Package for Social Science

Abstract

Decarbonizing energy production is a crucial lever for mitigating climate change. Despite impressive learning curves in relation to renewables, and high levels of socio-political as well as market acceptance, implementation is proving difficult due to a lack of local acceptance. A better understanding of the drivers underlying social acceptance is essential for helping policymakers and project developers craft new strategies for managing processes at the local level, and thus supporting the implementation of low-carbon policies. With this thesis, I increase understanding of the factors underlying social acceptance of renewables by focusing on the role of affect in the implementation of wind, solar and geothermal energy projects. I present recommendations to project developers and policy makers for better integrating energy projects into local communities, and highlight to researchers the importance of measuring affective factors, in addition to cognitive factors, to advance energy acceptance research. In the *first paper*, I explore people's affective reactions to wind energy and the impact of the latter on local attitudes towards wind energy projects. I find that affective evaluations of wind energy differ between mild and strong opponents. The results show that policymakers and project developers should not be blinded by the vocal opinions of strong opponents but pay more attention to those who have mixed feelings about the technology (i.e., the "silent majority"). In the *second paper*, I examine the role of installation size and affect in forming attitudes towards solar energy. Results reveal that when comparing solar and wind energy installations of similar sizes, the stronger preference for solar energy decreases to a similar level as that of wind energy. Policymakers may thus encounter comparable challenges with large-scale solar to those associated with wind energy projects. The study also shows that affect is especially important in shaping people's attitudes in the case of large-scale installations. In the *third paper*, I investigate the role of seismic risk of deep geothermal energy on affect, emotions, and attitudes towards shallow and deep geothermal projects. Results show that being informed about geothermal energy can positively impact people's affect about the technology. They also show that a spillover effect of seismic risk awareness on perceptions about shallow geothermal projects is identifiable in terms of affect and emotions, but not through attitudes, highlighting the importance of measuring affective factors in addition to cognitive factors in energy acceptance research.

Zusammenfassung

Die Dekarbonisierung der Energieerzeugung ist ein entscheidender Hebel zur Eindämmung des Klimawandels. Trotz beeindruckender Lernkurven in Bezug auf erneuerbare Energien und hoher gesellschaftspolitischer sowie marktwirtschaftlicher Akzeptanz erweist sich die Umsetzung aufgrund mangelnder lokaler Akzeptanz als schwierig. Ein besseres Verständnis der Triebkräfte, die der gesellschaftlichen Akzeptanz zugrunde liegen, ist unerlässlich, um politischen Entscheidungsträgern und Projektentwicklern zu helfen, neue Strategien für die Umsetzung von klima- und energiepolitischen Massnahmen auf lokaler Ebene vorantreiben. Mit dieser Arbeit vertiefe ich das Verständnis der Faktoren, die der gesellschaftlichen Akzeptanz von erneuerbaren Energien zugrunde liegen, indem ich mich auf die Rolle des Affekts bei der Umsetzung von Wind-, Solar- und Geothermieprojekten fokussiere. Ich präsentiere Projektentwicklern und politischen Entscheidungsträgern Empfehlungen für eine bessere Integration von Energieprojekten in lokale Gemeinschaften und zeige Forschern die Bedeutung der Messung affektiver Faktoren zusätzlich zu den kognitiven Faktoren auf, um die Energieakzeptanzforschung voranzutreiben. Im *ersten Beitrag* untersuche ich die affektiven Reaktionen der Menschen auf Windenergie und deren Einfluss auf die lokale Einstellung zu Windenergieprojekten. Ich zeige, dass sich die affektiven Bewertungen von Windenergie zwischen milden und starken Gegnern unterscheiden. Die Ergebnisse zeigen, dass politische Entscheidungsträger und Projektentwickler sich nicht von den lautstarken Meinungen der starken Gegner blenden lassen sollten, sondern denjenigen mehr Aufmerksamkeit schenken sollten, die gemischte Gefühle gegenüber der Technologie haben (der "schweigenden Mehrheit"). Im *zweiten Beitrag* untersuche ich die Rolle der Anlagengrösse und des Affekts bei der Entstehung von Einstellungen zur Solarenergie. Die Ergebnisse zeigen, dass beim Vergleich von Solar- und Windenergieanlagen ähnlicher Grösse die stärkere Präferenz für Solarenergie auf ein ähnliches Niveau sinkt wie bei der Windenergie. Politische Entscheidungsträger könnten daher bei grossflächigen Solaranlagen auf ähnliche Herausforderungen wie bei Windenergieprojekten stossen. Die Studie zeigt auch, dass Affekte bei Grossanlagen besonders wichtig für die Einstellung der Menschen sind. Im *dritten Beitrag* untersuche ich die Rolle des seismischen Risikos der Tiefengeothermie auf Affekte, Emotionen und Einstellungen gegenüber oberflächennahen, sowie tiefen Geothermieprojekten. Die Ergebnisse zeigen, dass Informationen über Geothermie den Affekt der Menschen auf die Technologie positiv beeinflussen können. Die

Ergebnisse zeigen auch, dass ein Spillover-Effekt des seismischen Risikobewusstseins auf die Wahrnehmung von oberflächennahen Geothermieprojekten in Bezug auf Affekt und Emotionen erkennbar ist, jedoch nicht auf die Einstellungen. Dies hebt die wichtige Bedeutung der Messung affektiver Faktoren zusätzlich zu kognitiven Faktoren in der Energie-Akzeptanzforschung hervor.

Introductory Chapter¹

1. Overall background and problem statement

There is almost unequivocal agreement among scientists that the climate of our earth is changing (Anderegg et al., 2010). It is now clearer than ever that climate change is in large part caused by the release of greenhouse gas (GHG) emissions that are triggered by human activity (IPCC, 2014). The consequences of climate change include air pollution, extreme weather events, rising sea levels, and a loss of biodiversity (IPCC, 2018). These effects are already being felt around the world, and will increase in severity if no significant measures are taken (Peters et al., 2020). To foster a response to these effects, during the COP21 (conference of parties) in 2015, close to 200 countries gathered and agreed to enforce regulations that would limit the potential increase in global temperature to well below two degrees Celsius, but if possible one and half, above pre-industrial levels (UNFCCC, 2017).

One promising pathway for achieving this United Nations Framework Convention on Climate Change (UNFCCC) goal is decarbonizing the electricity supply – which accounts for a significant 41% of global CO₂ emissions (IEA, 2020). Such decarbonization requires transitioning from fossil fuels to renewables. On a global scale, recent forecasts from the International Energy Agency (IEA) show that the potential of renewable electrical capacity is high: the IEA estimates that it will increase by roughly 50% by 2024 compared to 2018 (IAE, 2019a). Solar PV, including utility-scale and distributed applications such as solar rooftop PV, will account for 60% of the renewable capacity expansion over this period, followed by wind, hydropower, bioenergy and geothermal energy (IEA, 2019a).

In line with the Paris Agreement, countries such as the United Kingdom, India, Germany, and Switzerland have defined transition targets for their energy strategies (SFOE, 2017; UNFCCC, 2017; Barton et al., 2018). In the case of Switzerland, for example, the population voted to set national targets for the expansion of renewables when it approved

¹ Please note that if specific notes are made to the papers they are referred to as *Paper 1* (Cousse, Wüstenhagen and Schneider, 2020), *Paper 2* (Cousse) and *Paper 3* (Cousse, Trutnevyte, Hahnel, forthcoming); several sentences of this chapter are drawn from *Paper 1*, *Paper 2* and *Paper 3* without explicit citation. Note that the first person is used for consistency reasons in the introductory chapter, however Paper 1 and Paper 3 were elaborated in collaboration with the above cited authors.

the Swiss Energy Strategy 2050 (SFOE, 2017). With this strategy, Switzerland plans to increase the production of renewables (except for hydropower) to at least 11,400 gigawatt-hours by 2035 (SFOE, 2017). To reach such targets, policymakers and governments around the world have introduced policies and subsidies that promote the use of renewables (European Commission, 2019; Pischke et al., 2019).

However, despite these promising forecasts and policies, progress with increasing the share of renewables (Ecofys, 2018), as well as the phasing out of fossil fuels, (Tollefson, 2018) remains too slow in some countries. In Switzerland, for example, national production of solar and wind currently accounts only for 4.2% of total electricity production – the equivalent of 284 kilowatt-hours per capita (SES, 2020). The reasons for this are manifold, and include policy, technological, and social acceptance-related challenges (Sovacool, 2017; Hiard, 2020). On the one hand, although renewables continue to be promoted through diverse policies, policies for increasing divestment from fossil energy have not been designed with ambitious enough timelines (e.g., Rinscheid & Wüstenhagen, 2018). On the other hand, renewable energy projects often face challenges when it comes to their implementation at the local level. In this regard, studies such as the Stern Review on the Economics of Climate Change claim that the elimination of barriers to behavioral change should be one of three essential components of energy and climate policy, alongside policy and technological changes (Stern, 2007). As such, an energy system is not simply a collection of different technologies and associated infrastructure, but a sociotechnical system deeply embedded in society. (Miller et al., 2013). This suggests that there is a need to go beyond techno-economic rationalism and to account for individual energy-related decisions and behaviors, highlighting the importance of research in this domain.

Accordingly, one challenge regarding the deployment of renewables is related to social acceptance, and, more precisely, a gap between generally positive attitudes towards renewables (i.e., socio-political acceptance) versus attitudes towards the implementation of energy projects at the local level (i.e., community acceptance) (Wüstenhagen et al., 2007). Indeed, while national polls find that the population tends to report positive attitudes towards renewables, these attitudes do not directly translate into the uptake of renewable energy technologies (Larson & Krannich, 2016; Janhunen et al., 2018; Cousse & Wüstenhagen, 2019). Literature on social acceptance of renewables has investigated this gap, and interest into the topic has been steeply rising over the last two decades (Tabi &

Wüstenhagen, 2017), given its crucial role in the successful implementation of energy projects (Stern, 2007), and ultimately in the transition to a more sustainable energy system. Strengthening local acceptance thus appears to be the main challenge to the deployment of renewable energy projects (Ellis & Ferraro, 2016). Further, one aspect that has been particularly under-researched so far – in contrast to cognitive processes – is the role of affect and emotions in social acceptance of renewable energy (Russell & Firestone, 2021), and overall, in energy-related decisions (Brosch et al., 2014).

To summarize, without local acceptance, even in the case of favorable market and socio-political acceptance, the deployment of renewables may hit roadblocks. Further, while multiple factors can affect local acceptance, it is mostly cognitive processes that have been studied so far. Accordingly, this doctoral thesis aims to contribute novel insights to the overall stream of research about social acceptance of renewables by focusing on the role of affect and emotions on local acceptance. Additionally, it focuses on three specific renewable energy sources: wind, solar, and geothermal energy, which are key elements for achieving the goal of the Swiss Energy Strategy 2050 (SuisseEnergie, 2019). Overall, I aim to provide key stakeholders – such as utilities that face the challenge of designing and communicating about their projects so that they enjoy high local acceptance levels – and policy makers – who must take social acceptance into account as an important component during the project-implementation process – with recommendations for the smoother and more successful implementation of renewable energy projects. Hence, insights from this thesis can also contribute to achieving the goals of the Swiss Energy Strategy 2050, and ultimately, the Paris Agreement.

2. Background and research questions

2.1 Social acceptance of renewables: concept and prior research

The acceptance of energy sources is a far-reaching concept that various scientific disciplines have investigated, from social sciences to politics and industry (von Wirth et al., 2018). Discussions are still ongoing in the literature about its exact meaning (Schumacher, 2019). Specific to energy technologies, acceptance can be defined as a “positive attitude toward a technology or measure that is likely to lead to supporting behavior for the respective technology if necessary or requested.” (von Wirth et al., 2018, p.261). One of

the most cited papers on the concept of social acceptance was written by Wüstenhagen et al. (2007). This paper identifies three dimensions of social acceptance that I referred to earlier; namely, socio-political-, market-, and community acceptance (Wüstenhagen et al., 2007). Socio-political acceptance refers to general acceptance, and public opinion regarding technological development, community acceptance refers to acceptance of specific projects at the local level, namely by residents, organizations, and/or local authorities, while market acceptance refers to the willingness of financial institutions to invest in technology and consumers to adopt renewable energy technologies (Wüstenhagen et al., 2007). These three levels are not distinct, but interrelated. For example, policies at the socio-political level may change and increase the related risks, undermining market acceptance. Alternatively, issues related to community acceptance may force changes at the socio-political level. Social acceptance is thus formed at different levels and is affected by a diversity of actors and the relationships between them (Upham et al., 2015). A variety of studies have found a high level of socio-political acceptance for renewables (Langer et al., 2016; Ellis & Ferraro, 2016; Cousse & Wüstenhagen, 2018; Dubois et al., 2019). Moreover, in various parts of the world, renewables are currently the most cost-effective source of new electricity generation (IRENA, 2019), which is favorable in terms of their market acceptance. This has led researchers to argue that these two levels (i.e., socio-political and market acceptance) are not the main barriers to social acceptance (Firestone et al., 2018; Dwyer & Bidwell, 2019), but rather community acceptance is.

Concern at the local level is not surprising given that renewable energy projects generate significant environmental, social and economic impacts (Devine-Wright & Batel, 2017). Research on social acceptance of wind energy has delved into these concerns and identified the phenomenon known as ‘NIMBYism’ (Not In My Back Yard) (Bosley & Bosley, 1988; Dear, 1992). However, this concept has been criticized for giving a too simplistic explanation of the low level of local acceptance (e.g., Devine-Wright, 2005; Wolsink, 2006; Bell et al., 2013), while some research has found evidence for the opposite effect – namely a PIMBY (Please In My Backyard) reaction (e.g., Brauholtz, 2003; Wolsink, 2006; van der Horst, 2007; Ellis & Ferraro, 2016; Rand & Hoen, 2017). Following this, research on social acceptance of energy technologies (mainly based on wind energy research), has recognized the importance of different types of factors upon acceptance (Devine-Wright, 2013). First, these include personal factors such as political, social, individuals’ socio-

demographics characteristics (e.g., age, gender, and income) and environmental beliefs and values (e.g., Firestone et al., 2009; Swofford & Slattery, 2010). Second, factors specific to the projects also matter. They range from the level of trust in the company launching a project, (Midden & Huijts, 2009) to procedural justice, namely how decisions related to the projects are taken (Gross, 2007), and distributional justice, which concerns how costs and benefits are shared between stakeholders (Cass et al., 2010). Third, the place-based approach looks into where energy projects are sited. The latter looks at local residents' emotional attachments to the place where a project will be (has been) instigated, and the meanings associated with that place (e.g., Devine-Wright, 2009; Devine-Wright & Batel, 2017).

2.2 Wind, solar and geothermal energy: a variety of challenges

The thesis focuses on three specific renewable energy technologies – wind, solar, and geothermal energy – as these are seen as important technologies for decarbonizing the electricity system worldwide (IPCC, 2007), including in Switzerland (SuisseEnergie, 2019). In this context, solar energy refers to solar photovoltaics (solar PV), and geothermal energy to deep geothermal energy (DGE). Indeed, while solar energy can produce both heat and electricity, only solar PV converts sunlight into electricity (SFOE, 2020a), and only DGE can produce electricity, as opposed to shallow and medium depth geothermal energy (SFOE, 2020b).

The deployment of wind, solar and geothermal energy faces different challenges. A key difference relates to the level of maturity of the technologies. While solar and wind energy technologies can be considered mature in terms of their technological learning curves (IRENA 2016; Vartiainen et al., 2019; BNEF, 2020), DGE still faces multiple technical difficulties and uncertainties (Ejderyan et al., 2019). In the Swiss context, this difference is even more pronounced, as knowledge about the deep subsurface is low compared that of countries that have an oil and gas industry (Ejderyan et al., 2019). Second, socio-political and community acceptance of these three energy sources differ. In Switzerland, from a socio-political acceptance point of view, the preferred electricity supply options are solar,

wind, and hydropower, while DGE is the least well supported renewable energy technology (Blumer et al., 2018). The low technological maturity level and its related risks has been identified as a main factor for its relatively low acceptance level (e.g., Knoblauch et al., 2019). From a community acceptance point of view, both wind and DGE projects are facing resistance, while socio-political acceptance of solar energy translates generally well into community acceptance (Horbaty et al., 2012; Leucht, 2012; Walker & Baxter, 2017; Blumer et al., 2018). In Switzerland, this has led to a situation where solar power generation has grown at double-digit growth rates in recent years, whereas the share of wind power has remained stable (see Figure 1). Regarding geothermal energy, no electricity is currently being produced from geothermal projects (SFOE, 2020b). The Swiss Energy Strategy 2050 is however planning to have 4'400 GWh produced by deep geothermal energy by 2050 (Geothermie-suisse, n.a). Related to social acceptance of the technologies, another important difference between the three technologies pertains to the size of the installation. While solar energy installations can be small (e.g., solar rooftop), wind and deep geothermal energy production require relatively large installations. As literature in social acceptance of energy technologies suggests that the fit of the energy installation to the landscape is a crucial factor to its acceptance (e.g., Wolsink, 2000; 2018a), technologies that can only be implemented on a large scale may face more important challenges from a social acceptance perspective.

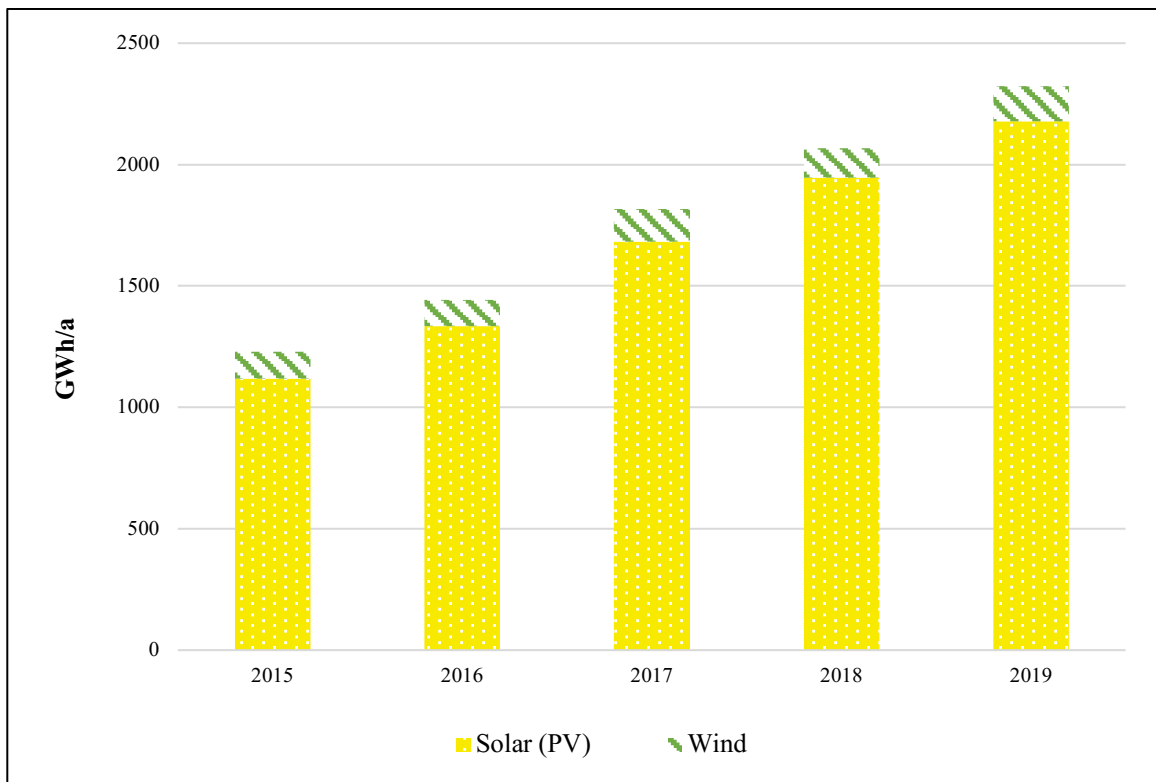


Figure 1: Cumulative renewable electricity production of solar and wind energy in Switzerland

As opposed to the abundant literature on wind energy, social acceptance of solar energy has been less researched (Sovacool & Ratan, 2012; Brewer et al., 2015; Carlisle et al., 2015; Michel et al., 2015; Khan & Arsalan, 2016; Sütterlin & Siegrist, 2017; Vuichard et al., 2021;), and even less geothermal energy (Dowd et al., 2011; Pellizzone et al., 2015; Volken et al., 2018; Knoblauch et al., 2018; Knoblauch et al., 2019). Nonetheless, it has been highlighted that solar energy is seen as one of the most promising sources of green electricity for the future (Creutzig et al., 2017) and enjoys the highest socio-political acceptance (e.g., Kaenzig et al., 2013; Volken et al., 2018). However, the large deployment of solar energy, as planned in different national energy strategies (e.g., SES, 2020; Jäger-Waldau, 2019), will lead to significant transformation of the landscape and thus affect society (Sánchez-Pantoja et al., 2018). As such, in spite of the high level of socio-political acceptance of solar energy, the large deployment of solar installations may cause an aesthetic impact which potentially affects community acceptance negatively (Chiabrando et al., 2009; Dubey et al., 2013; Hernandez et al., 2014; Delfanti et al., 2016; Sánchez-Pantoja et al., 2018). This may, for example, be the case with utility-scale solar power plants that are forecasted to represent 55% of total solar PV (photovoltaic) expansion by 2024

(IEA, 2019a). Despite this, there exists little research about social acceptance of utility-scale solar photovoltaic (Brewer et al., 2015; Carlisle et al., 2015; Michel et al., 2015; Vuichard et al., 2021).

Concerning geothermal energy, related research has highlighted that the public does not yet have an established preference towards the technology (Pellizzzone et al., 2015; Blumer et al., 2018) has little knowledge about it (Pellizzzone et al., 2015; Dubois et al., 2019) and, after some cases of induced seismicity caused by some deep geothermal pilot projects (e.g., in Basel and St.Gallen, Switzerland and in Pohang, in South Korea), the strength of Swiss public support for this technology appears questionable (Blumer et al., 2018; Benighaus & Bleicher, 2019). Overall, we still have little insights into the main factors affecting the acceptance of geothermal energy (Hirschberg et al., 2015), and especially the local acceptance of geothermal energy projects, outside of the crucial role of induced seismic risk (Knoblauch et al., 2019) and the importance of engaging in an open dialogue with the population (Pellizzzone et al., 2015; Trutnevyte & Wiemer, 2017).

2.3 Affect, emotions and energy-related decisions

The previous paragraphs highlight that much of the current research concerning social acceptance of energy technologies can be characterized as cognitive in nature. However, some studies have started analyzing the affective side of decision-making regarding energy projects (Cass & Walker, 2009; Truelove, 2012; Visschers & Siegrist, 2014; Sütterlin & Siegrist, 2017; Jobin & Siegrist, 2018; Jobin et al., 2019; Dubois et al., 2019). In this section, I review the literature that has investigated affect and emotions, and highlight its importance within the context of the acceptance of renewables.

Across various scientific fields, most theoretical approaches that have tried to increase understanding about energy-related decisions have focused mainly on cognitive processes as highlighted by Brosch et al. (2014). Cognitive processes pertain to the analytical and effortful processes on which people base their decisions, and involve thoughts, beliefs, and perceptions (Weber & Johnson, 2009). As opposed to cognitive processes, affective processes are based on associative and intuitive processes, which require less efforts (Weber & Johnson, 2009). Dual-process theories of decision making (Kahneman, 2011) suggest that affective and cognitive factors interact in complex ways (Slovic et al., 2007).

As such, there exists now an understanding that in many cases, decisions are not only based on what individuals think or know, but also on how they feel (Slovic et al., 2004). Despite this, theories that have taken into account the role of affective processes and emotions have often considered them as biases that impede rational thinking (e.g., Finucane et al., 2000). Accordingly, these theories have assumed that emotions undermine decision-making, as pointed out by Brosch et al. (2014). However, more recent research on emotions considers emotion and cognition not as separate or opposing processes, but instead sees them as complementary and deeply intertwined (Scherer, 2009; Brosch, 2013; Sander, 2013). These studies highlight that affect and emotions should be considered as essential processes that produce important information *in combination* with cognitive processes, rather than processes that hinder the latter (Brosch et al., 2014). Affect and emotion can be difficult to distinguish, and are not always defined in the same way. Yet, there have been efforts to clarify their respective meanings (Clore et al., 1987; Peters & Slovic, 2007; Brosch et al., 2014). Studies have also attempted to separate specific emotional responses such as ‘joy’ and ‘anger’ from the concept of affect (Rohse et al., 2020). Leiserowitz (2006), for example, distinguishes discrete emotions (e.g., anger and fear), from the concept of affect (a person’s good or bad, positive or negative feelings about an object) (p.46).

Studies which have investigated the affective side of energy-related decisions have empirically shown that emotion-related variables have an explanatory power in relation to energy-related decisions that is additional to that of models that include only cognitive variables (Brosch et al., 2014) such as those used in the theory of planned behavior (Ajzen, 1991), or in the value-belief norm model (Stern, 2000). These results highlight those emotional processes may influence energy-related decisions above and beyond the maximization of one’s interests or normative concerns (Brosch et al., 2014).

In research specific to the acceptance of renewable energy technologies, affective imagery has been used to measure the correlation between individuals’ perceptions of energy technologies and local (i.e., community level) versus general (i.e., socio-political level) acceptance (Truelove, 2012; Sütterlin & Siegrist, 2017). Affective imagery is a two-step methodology used to uncover the affective influences in decision-making (Leiserowitz, 2006). In a first step, respondents are asked to list their spontaneous associations regarding a stimulus (e.g., “wind energy”), while in a second step they are asked to rate the associations they provided on a bipolar affect scale. Truelove (2012) found that her

affective model significantly predicted the local acceptance of wind energy, but not general acceptance. Sütterlin and Siegrist (2014) used the same methodology to investigate the affect elicited by solar energy, and found that the public associate solar power with highly positive imagery. Jobin et al. (2019) explored the extent to which affect elicited by energy technologies predicts individuals' preferred energy portfolios. The authors found that affective reactions to energy technologies influence both the way they look for information as well as their energy technologies preferences. In a similar way, Jobin and Siegrist (2018) found that the affect elicited by specific energy technologies is the most important driver of the proportion of technologies included in respondents' preferred portfolios. These results empirically support the technology acceptance framework (TAF) of Huijts et al. (2012), which proposes that both positive and negative affect, along with rational evaluation, influence attitudes.

With regard to the role of emotions, researchers have shown that different emotions of the same valence (e.g., anger and fear) can lead to different behavioral responses (Lerner & Keltner, 2001; Lerner & Keltner, 2000). Based on this, Huijts (2018) investigated the factors that influence anger, fear, joy, and pride evoked by hydrogen fuel stations, and found that people feel significantly angrier when they perceive more procedural and distributive unfairness, while environmental benefits and local usefulness caused people to experience a significantly higher amount of joy. These results are in line with the theoretical framework proposed by Perlaviciute et al. (2018) that argues that the strength of emotions that are elicited depends on the extent to which different project characteristics support or infringe individuals' core values.

While these studies provide interesting insights and have been crucial in showing that affect matters in decision-making, we still have little insights into the nature of this affect, how it is formed, and what additional insights into the social acceptance of energy technologies, especially at the local level, it can bring us. Further, practitioners in the energy sector often still come to the conclusion that people are being irrational or overacting when they exhibit negative emotions in relation to energy projects (Perlaviciute et al., 2018). Based on this view, they often respond to public emotions in ineffective ways, such as ignoring emotions and moving on with a project, or immediately stopping it (Perlaviciute et al., 2018). These responses are problematic and call for a better understanding of the affect and emotions elicited by energy sources and energy projects. The latter may help

equip policymakers and project developers with more effective communication strategies that take into account the emotional aspect of energy technologies, thereby reconceptualizing the ‘pure rational actor’ approach to interaction with communities into one that also pays attention to the public’s emotions. If sustainable energy projects get cancelled immediately, or face long delays as soon as they elicit negative emotions, the energy transition could be seriously hindered.

The previous paragraphs illustrate that greater insights into the social acceptance of renewable energy are crucial for their deployment. Based on the different challenges solar, wind, and geothermal energy are facing at the local level, it appears to be relevant to explore how different aspects (e.g., installation size, risk, and affect) can influence the implementation of these energy sources. Previous research has also highlighted that deeper insights into the affective side of decision-making are not only lacking, but could greatly contribute to creating a better approach to how communication around existing energy projects could be adapted, or how new projects could be promoted in more successful ways. Thus, with this thesis I seek to contribute to the better understanding and management of the elements of social acceptance of wind energy, solar energy, and geothermal energy, with a focus on the affective side of decision-making. Overall, I aim to provide project developers and policy makers with recommendations for the smoother and more successful implementation of renewable energy projects. Hence, insights from this thesis also contribute to achieving the goals of the Swiss Energy Strategy 2050 and ultimately, the Paris Agreement. Overall, this dissertation aims to close the above-mentioned gaps by responding to the following general research questions. The more detailed research questions addressed in *Papers 1-3* are outlined in Section 3.

1. *What is the role of affect in explaining local acceptance of renewable energy projects?*
2. *How do installation size and technological maturity influence local acceptance of renewable energy projects?*

3. Overview research papers and objectives

The objective of this doctoral thesis is to shed some light on the research gaps and questions highlighted in Section 2, by means of presenting three research papers. The research objectives and publication status of each of these three papers are described below in more detail. Table 1 provides an overview of all three papers by summarizing the title, authorship, research objectives, methodologies applied and publication status at the time of the submission.

Paper 1 of the thesis is entitled “Mixed feelings on wind energy: Affective imagery and local concern driving social acceptance in Switzerland.” Based on a Swiss-wide representative sample of 1’111 respondents, this research paper investigates individuals’ spontaneous associations elicited by wind power and the associations’ related affective evaluations (i.e., affective imagery, Leiserowitz, 2006), to gain insights on the processes influencing local attitudes towards wind energy projects. Precisely, I went beyond prior studies by (1) analyzing the sequencing of the associations provided by respondents who thought of wind power; (2) exploring how the associations and related affect varied based on individuals’ characteristics; (3) comparing the associations of opponents and supporters by differentiating between strong and mild variants to gain insights on the perceptions of the silent majority (King et al., 1971; Leitch & Davenport, 2006). In doing so, this paper was the first to conduct an extensive analysis of people’s affective imagery regarding wind power. Results reveal that affective imagery plays a key role in forming public perceptions and consequently influences support or opposition to the implementation of wind power projects. Moreover, the results highlight that significant differences in affective imagery exist between strong and mild supporters and opponents, signaling that the segmentation of target groups is called for when trying to manage processes of local acceptance. The findings also highlight that different types of affective imagery exist depending on socio-demographic variables such as political orientation or age group. Overall, the results show that the issue of local acceptance is more complex than a pro-wind versus anti-wind discourse (Walker et al., 2014; Rand & Hoen, 2017). As such, *Paper 1* fills some of the gaps identified in the previous section by providing insights into the nature of the affect elicited by wind power and the factors underlying the latter, as well as increases

comprehension of the factors influencing local acceptance of energy projects through the investigation of affect. *Paper 1* shows that project developers and policymakers should not stop at the vocal opinions of strong supporters or opponents, but pay much more attention to the “silent majority” (Gross, 2007) of people who are initially undecided. Generally, it points out to practitioners that while factual information is important to attend to people’s concerns, being mindful of negative emotions and strengthening positive ones is an equally important part of managing acceptance of wind energy projects at the local level. *Paper 1* has been published in *Energy Research and Social Science*. An earlier version of this paper has been presented in June 2019 at the 4th International Conference on Public Policy in Montreal, Canada

Paper 2, entitled “Still in love with solar energy? Installation size, affect, and the social acceptance of renewable energy technologies”, explores how attitudes towards solar energy vary based on the size of the solar energy installations, how the latter compare to attitudes towards wind energy, and what the role of affect is in the former. While solar energy enjoys a high level of socio-political acceptance and appears to be greatly preferred to other renewables (Gamma et al., 2017; Sütterlin & Siegrist, 2017; Cranmer et al., 2020), it is still unclear whether the preference for this technology persists if the technology is deployed on a larger scale. Based on a Swiss-wide representative survey ($n = 601$) using a between-subjects design, *Paper 2* finds that the stronger preference for solar power decreases to a similar level as that for wind energy when comparing installations of similar sizes, and that affect plays an important role in forming people’s attitudes, especially concerning large-scale installations. For practitioners, *Paper 2* highlights that solar energy may not easily be scaled up from a social acceptance perspective, thus similar problems may be encountered with large-scale solar as with other technologies deployed on a large scale, such as wind energy. It further underlines the need for those practitioners who aim to deploy renewables on a large scale to attend to the affective reactions elicited by energy projects among the population. As such, *Paper 2* fills some gaps identified in Section 2 by increasing insights both into the social acceptance of utility-scale solar PV (Brewer et al., 2015; Carlisle et al., 2015; Michel et al., 2015; Vuichard et al., 2021), and into the affective components underlying the opposition to energy projects encountered at the local level. This paper has been published in *Renewable and Sustainable Energy Reviews*. An earlier version of this

paper was accepted for the 43rd IAEE International Conference in Paris, France, postponed to July 2021.

Paper 3 is entitled “Tell me how you feel about geothermal energy: Affect as a revealing factor of the role of seismic risk on public acceptance.” It also harnesses the power of affect to increase understanding of the local acceptance of renewable energy projects, while focusing, this time, on geothermal energy. In addition to *Papers 1* and *2*, it also explores discrete emotions, in addition to affect. Specifically, *Paper 3* first investigates the effect of information on seismic risk related to deep geothermal projects – namely, on affect, emotions, and the perceived risks and benefits of deep as well as shallow geothermal projects. Second, it explores how presenting information about seismic risk in a neutral versus more negative, emotionally laden manner may affect the latter outcomes. Through these objectives, the study addresses some of the gaps identified in Section 2 by providing more insights into the factors that underlie and influence perceptions of geothermal energy, and into how affect and emotions may help researchers to better understand perceptions about energy projects. Two randomized, between-subjects experimental studies were conducted with representative samples of the Swiss population ($N_1 = 1,018$; $N_2 = 1,007$), with Study 2 replicating Study 1 with more negative, emotionally laden information about seismic risk. *Paper 3* reveals that information about geothermal energy, including its seismic risk, can positively impact people’s affect about the technology, and that a spillover effect of seismic risk awareness in relation to shallow geothermal projects is identified for emotions and perceptions of risks and benefits, but not for attitudes. For project developers and policymakers, the results suggest that the Swiss population is open to the use of both shallow and deep geothermal energy, but that early communication will be key to avoiding a decline in acceptance. They also highlight the importance of measuring affective in addition to cognitive factors in energy acceptance research, and the fact that making information about seismic risk more negative – such as depicted in the media or by oppositional party-driven movements – also negatively affects perceptions of the technology. *Paper 3* has been submitted to Energy Policy and is currently in a second round of review. An earlier version of the paper was presented at the ECPR 2020 General Conference, held online in August 2020.

No	Title	Authors	Research objectives	Methodology	Publication status
1	Mixed feelings on wind energy: Affective imagery and local concern driving social acceptance in Switzerland	Julia Cousse ^a , Rolf Wüstenhagen ^a , Nina Schneider ^a	- Investigate affective imagery elicited by wind power and its impact on local attitudes - Explore the sequencing of affective imagery elicited by wind power and its role on attitude formation	Online survey, ANOVA and chi-square analysis, qualitative coding	Published in <i>Energy Research and Social Science</i> , Volume 70, 2020: 101676 <i>Impact Factor: 4.771</i>
2	Still in love with solar energy? Installation size, affect, and the social acceptance of renewable energy technologies	Julia Cousse ^a	Examine how local attitudes towards solar energy vary based on the size of installations and what the role of affect is in the latter	Experimental online survey design, ANOVA and regression analysis	Published in <i>Renewable and Sustainable Energy Reviews</i> , Volume 145, 2021: 111107 <i>Impact factor: 12.110</i>
3	Tell me how you feel about geothermal energy: Affect as a revealing factor of the role of seismic risk on public acceptance	Julia Cousse ^a , Evelina Trutnevyte ^b , Ulf Hahnel ^c	Investigate the impact of neutral versus more negative, emotionally-laden information about seismic risk of deep geothermal projects on affect, emotions and attitudes towards shallow/deep geothermal projects	Experimental online survey design, ANOVA analysis, qualitative coding	Under review by <i>Energy Policy</i> <i>Impact Factor: 5.042</i>

^a Institute for Economy and the Environment, University of St.Gallen, Switzerland; ^b Renewable Energy Systems, Institute for Environmental Sciences (ISE), Section of Earth and Environmental Sciences, University of Geneva, Switzerland; ^c Department of Psychology and Swiss Center for Affective Sciences, University of Geneva, Switzerland

Table 1: Overview of the papers in the dissertation

4. Methodology and data

All three papers of this doctoral thesis are reports on empirical studies that employed quantitative research methods and are based on the case of Switzerland. Switzerland is a direct democracy - its citizens can express their points of view about energy policies or energy projects not only when voting, but also through other pathways such as consultation processes (Blumer et al., 2018). Based on this system, policymakers in Switzerland as well as energy project developers, must build public support to an even greater extent than in other democracies (Blumer et al., 2018). The Swiss Energy Strategy 2050 (ES2050) is based on two main building blocks: a significant reduction in energy demand, and a large increase in the production of renewables in the country. The latter goal is of even greater importance now that the country has planned a gradual phase-out of its nuclear power plants (SFOE, 2017). A significant share of this additional renewable energy production is planned to come from solar and wind (SFOE, 2017). Yet, the ES2050 centers on using hydropower and deep geothermal energy to partly replace the base load capacity currently supplied by nuclear energy (SFOE, 2017). Hence, the Swiss population was considered a convenient and interesting sample through which studying social acceptance of wind, solar, and geothermal energy.

Depending on the respective research questions, different methodologies were used. These are briefly described below, and further detailed in each paper. For all three papers, study participants were drawn from an actively recruited Swiss online consumer panel ($N = 100,000$) operated by an experienced market research agency and representative of the adult population from the German- and French-speaking parts of Switzerland. Further, for *Papers 2* and *3* empirical experiments were used. Empirical experiments are widely employed and accepted in academic research (e.g., Kirk, 2012; Aaker et al., 2013) as they offer a unique opportunity to investigate the effects of a variety of factors on the outcome of a dependent variable, while all other factors can be held constant (Kirk, 2012; Aaker et al., 2013).

For *Paper 1*, a representative sample ($N = 1,111$) was collected through stratifying the population by gender, education, age, political orientation, and geographical region.

Moreover, the sample was boosted ($N = 180$) with respondents living close to pre-existing or planned wind energy projects based on data from the Swiss Federal Office of Energy (SFOE). The analysis focused on better understanding how the associations elicited by wind power and related affect (i.e., affective imagery) vary according to individuals' characteristics, and how this can help generate more insights into local acceptance. For measuring affective imagery elicited by wind power, the method of continued word associations was used (Slovic et al., 1991; Peters & Slovic, 1996;). Using a qualitative analysis, I developed the coding system and categorized all the associations. In a second step, a second author coded all associations independently. After categorizing the associations, I used simple relative frequency and mean averages to delve into the affective imagery elicited throughout the sample group, and then used ANOVAs (analysis of variances) and chi-square tests to investigate how the affective evaluations varied based on the individuals' characteristics (i.e., socio-demographics and attitudes towards wind energy projects). Next, a linear regression was run to measure the relationship between affect and local attitude, while controlling for important variables such as political orientation and rural versus urban environments. Finally, to investigate whether the sequence in which affective imagery is elicited matters in terms of attitude formation, a variable was created to indicate in which order respondents provided negative and positive associations. In this regard, I compared the evaluation of the first association that was given to the average evaluation of all subsequent associations using ANOVA.

For *Paper 2*, the data consisted of 601 respondents. The sample was representative of the Swiss population with regard to gender, age, geographical region, and political orientation. The analysis focused on how specific attitudes towards solar energy vary based on the size of the installation (solar rooftop versus utility-scale solar), and compared these to specific attitudes towards wind energy installations. Further, the role of affect in the latter was investigated. For this purpose, all participants were first surveyed to reveal their general spontaneous associations and related feelings elicited by the stimulus “wind” and “solar” energy (i.e., the words) using the method of continued word association (Slovic et al., 1991). In a second step, using an experimental between-subjects design, each participant was randomly assigned to one treatment group and presented either with pictures of solar park, rooftop solar, or wind park installations. Experimental survey designs are considered to be unobscured by other processes (Kirk, 1995; Webster & Sell, 2007) and can help with

overcoming the methodological limitations associated with mostly observational data (Yildiz & Sagebiel, 2019). Additionally, the use of pictures in surveys has been shown to be very helpful for understanding people's perceptions (e.g., Junker & Buchecker, 2008; Soliva et al., 2008). Further, the use of pictures was deemed to be particularly relevant in the context of this study to ensure that participants mentally visualized similar installations. The method of continued word association was also used to measure affective reactions to the pictures. In total, each respondent was exposed to two pictures in two very different settings (referred to as Scenario 1: Alpine, and Scenario 2: Midlands) to control for the effect of the surrounding landscape and test whether the differences observed between solar and wind energy installations were sustained in different settings. Last, the pictures were selected to represent environments that were not sterile but instead could elicit emotional reactions from respondents (i.e., real Swiss landscapes).

For *Paper 3*, the data was collected through two different surveys. The samples ($N_1 = 1'018$; $N_2 = 1'007$) were representative of the Swiss population with regards to gender, age, geographical region, and political orientation. The analysis focused on (1) the role of information about the seismic risk of deep geothermal projects on affect, emotions, attitudes, and the perceived costs and benefits of shallow and deep geothermal projects, (2) how presenting information about seismic risk in a neutral versus more negative, emotionally laden manner influences the target outcomes. To measure this, an experimental-survey design was selected, which allowed to establish a connection between information about the seismic risk as the independent variable and attitudes, affect, emotions, and perceived risks and benefits as the dependent variables. Specifically, the study was based on two between-subjects experimental factors: information about seismic risk (absent/present) and type of project (shallow/deep), making four different experimental groups, to which respondents were randomly assigned. Further, the research was based on two complementary experimental studies. Specifically, in Study 1, information about seismic risk was presented in a neutral manner, while in Study 2 information was presented in a more negative and emotionally laden manner, with all other elements *ceteris paribus*. In terms of analysis, I used ANOVAs as well as independent t-tests to measure the differences between the experimental groups, and used in-depth qualitative analysis to investigate the benefits of geothermal energy as perceived by the population.

5. Conceptual framework

The conceptual model presented in Figure 2 construes the three research foci of this dissertation. It builds on the dual-process model of energy support (Truelove, 2012), this being based on the literature on “risk as analysis” and “risk as feelings” (Loewenstein et al., 2001; Slovic, 2004). Truelove (2012) presented a model of energy support that posited and showed that affective and cognitive components jointly influence support for energy sources. I build on the established relationship between affect and “energy support” by focusing on the role of affect and the factors underlying it. While we already know that affect matters in decision-making regarding energy sources (e.g., Truelove, 2012), we have little insights into the nature of this affect, how it is formed, or what additional insights into perceptions of energy technologies it may offer (Perlaviciute et al., 2018). However, such insights would be useful to practitioners who struggle with knowing how to deal with people’s affective responses in an adequate way (Cass & Walker, 2009). The cognitive underpinnings of energy-related preferences are thus set aside for a deep dive into the affective components. While cognitive processes are of crucial importance, a large body of research has already investigated these (e.g., Greenberg, 2009; Rand & Hoen, 2017; Tabi & Wüstenhagen, 2017; Vuichard et al., 2019; Wolsink, 2018).

While Truelove (2012) used the terminology “energy support” to define attitudes towards energy sources in general, and towards energy projects, I employ the terminology of Walter (2014) and thus rename energy support as *attitudes towards energy technologies*. The dissertation aims at helping create a better understanding of *social* acceptance of renewable technologies. In the seminal work by Wüstenhagen et al. (2007), the socio-political dimension of social acceptance refers to the widest level of acceptance, involving key stakeholders, the public, and the political decision-makers affected by a specific national (i.e., non-site-specific) renewable-energy technology. This dimension is also referred to as “general acceptance”. The community acceptance dimension addresses the social acceptance of local (site-specific) projects. Local stakeholders, as well as local authorities and residents, are the focus of this level. Based on this, I argue that my measure finds itself between the socio-political and community acceptance dimensions. Indeed, while my measure is not site-specific, it focuses on local residents (i.e., community acceptance) measuring acceptance of a hypothetical project close to someone’s home (i.e., local). In this

way, it is close to community acceptance in that it investigates acceptance by (prospective) residents around a planned site. But it also has features of socio-political acceptance as I also investigate reactions with respect to the technologies more generally (i.e., affective reactions). To reflect these considerations, and my overall aim of contributing to the field of social acceptance of renewables, I added a box called “social acceptance of renewables”. I consider that all the relationships included in my conceptual model within the square contribute to a better understanding of social acceptance of renewables. Limitations associated with this approach are discussed in Section 6.3.

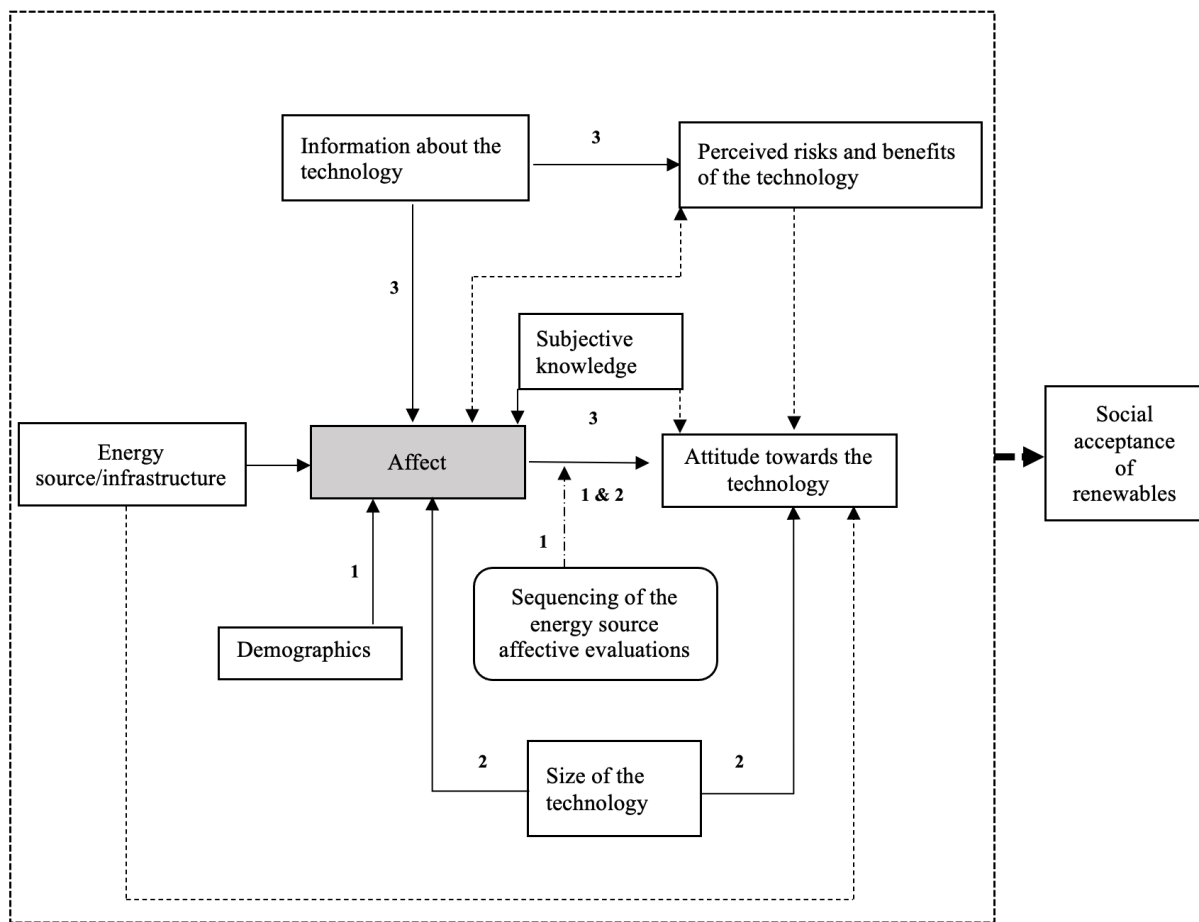


Figure 2: Conceptual framework of this dissertation

5.1 Embedding the three papers in the conceptual model

The three papers address the different foci within the conceptual model presented in Figure 2. The numbers by each of the arrows refer to the contribution of each paper. In

Paper 1, I investigate how affect elicited by an energy source on an abstract level (i.e., “wind energy”) influences attitudes towards the local implementation of this energy source (i.e., attitude towards the technology). Through an in-depth analysis of the affect and associations elicited, I go further than earlier studies by not only measuring whether affect influences attitudes, but how. Specifically, I look into the sequence in which associations elicited by the technology and its related affective evaluations guide attitude formation. While I do not investigate specifically whether the sequencing moderates the relationship between affect and attitude, I explore whether having a positive or negative first association about an energy technology matters to attitude formation. For this reason, the arrow is indicated using a different format (long dash shot). Besides the sequencing related to the energy source, affective evaluation is contained in another differently shaped box to reflect that it is not a new variable, but has been transformed from the affect variable. Additionally, while earlier studies have shown that demographics influence attitudes (e.g., Vuichard et al., 2019), I study how affect elicited by the energy source may vary based on demographics.

For *Paper 2*, I use affect to better understand the factors underlying the difference in acceptance between solar and wind energy. Knowing from research from *Paper 1*, that affect elicited by an energy source is strongly correlated to attitudes towards the local implementation of energy projects, I delve further into this relationship and explore how affect and attitude may vary based on the size of the energy installation.

In *Paper 3*, affect and the perceived risks and benefits of geothermal energy are used as “tools” to better understand local acceptance of shallow and deep geothermal projects. The model is further extended by adding information about the technology as a variable, with the aim of obtaining insights into how affect, emotions, and the perceived risks and benefits of a technology may be influenced by the information that is provided about the technology. Subjective knowledge is also explored as a factor that potentially influences the affect elicited by an energy technology. While I do not measure the role of perceived risks and benefits or subjective knowledge on attitudes, nor the link between affect and perceived risks and benefits, these relationships have been identified in previous studies (e.g., Loewenstein & Lerner 2003; Midden & Huijts, 2009; Huijts et al., 2012; Huijts, 2018; Siegrist & Arvai, 2020). They are thus represented with a dashed line.

6. Conclusion

The overarching aims of this dissertation are to investigate the factors underlying social acceptance of wind, solar and geothermal energy, with a focus on local implementation. The dissertation's three papers generated valuable insights into different theoretical fields, and are of use to energy project developers as well as policy makers. Herewith, I discuss the insights from each paper in more detail, differentiating between theoretical and practical contributions. Then, several research limitations are discussed, moving from a general to a paper-specific level, all of which could be the starting point for future scientific investigation. At the end of this chapter, I summarize the main conclusions of this dissertation.

6.1 Theoretical contributions

The three papers in this dissertation make important contributions to the research stream on social acceptance of renewable energy. More specifically, they provide new insights into the affective components driving local attitudes towards energy projects.

Paper 1 provides new insights into individuals' affective responses to local wind energy projects, contributing to a better understanding of the factors influencing local acceptance of such projects, and generating deeper knowledge about social acceptance of wind energy. Insights from the study support findings such as those by Walker et al. (2014) and Rand and Hoen (2017), in finding that the issue of social acceptance of wind energy is more complex than a pro-wind versus anti-wind discourse. This is illustrated in the results by the fact that I find significant differences in the associations elicited and the related affect between strong or mild supporters as well as between strong and mild opponents, with mild supporters and opponents being more alike in this respect than they are to the two extreme groups. *Paper 1* also supports the finding by Russell and Firestone (2021) and Perlaviciute et al. (2018) that affect matters in the formation of attitudes towards energy projects. Indeed, I find, while controlling for demographic variables, a strong correlation between the affective evaluations of the associations elicited by wind energy and respondents' attitudes towards energy projects. Moreover, an extensive analysis of related affective imagery (i.e.,

associations and related affect) reveals that while the first association that is elicited is on average positive, those that come after are consistently more negative than the first one. This may indicate that surveys that measure general acceptance may be good at capturing the first association that comes to people's minds when they think of wind energy, which is on average positive. However, they do not capture the secondary associations that are elicited, which are, on average, more negative than the first one. This finding may be relevant with regard to the discussion about the "acceptance gap" that has been identified in the literature (i.e., the fact that general surveys tend to be better at capturing first thoughts, but that the subsequent stages of the thought process actually matter for the overall evaluation of a project, and should thus be taken into account to get a better measure of local acceptance) (Walter, 2014; Enevoldsen & Sovacool, 2016). The study also contributes to the literature on query theory (e.g., Johnson et al., 2007; Weber & Johnson, 2011). A key prediction of query theory is that the order of queries elicited by a decision matters, and that it is the first query (or association elicited) that matters the most in terms of influencing a decision. While query theory provides an effective framework for predicting the attitudes of most respondents in the study, it does not seem to fully apply to one segment of the population (the mild opponents of wind energy projects), who could actually be crucial in terms of tipping the balance in favor of the projects.

Paper 2 investigates social acceptance of solar energy and, more specifically, whether its high general level of acceptance compared to other renewables, such as wind energy would perdure if deployed on a large scale. Literature on social acceptance of renewable energy has mainly focused on wind energy (Gaede & Rowlands, 2018), given opposition to it at the local level (e.g., Ellis & Ferraro, 2016). However, *Paper 2* shows that solar energy deployed on a large scale (e.g., solar parks) may face similar oppositional-related issues connected to the availability and use of land as have been identified in the case of wind parks (Jäger-Waldau et al., 2020). *Paper 2* also reveals novel findings regarding the affect elicited by solar energy by providing a more nuanced picture of the previously identified highly positive imagery about this energy source (Sütterlin & Siegrist, 2017). The results reveal that affect is not related to the energy source, per se, but rather to the type of the energy infrastructure (e.g., solar rooftop versus solar park). *Paper 2* also adds to the

literature that investigates the importance of affect in influencing attitudes towards energy projects (e.g., Jobin & Siegrist, 2018) by showing that affect is not only a crucial factor underlying attitudes towards energy projects, but that it may play an even greater role in the case of large-scale installations compared to small-scale ones.

Paper 3 contributes to the relatively new research stream that is focused on the social acceptance of geothermal energy (e.g., Knoblauch et al., 2019). With *Paper 3*, I add theoretical value by identifying important factors underlying social acceptance of geothermal energy through the investigation of affect and discrete emotions. In line with previous findings by Knoblauch et al. (2019), the study highlights that the population may be more willing to accept seismic risk if the related benefits are perceived to exceed the drawbacks. The results are also in line with previous studies that showed that the more one knows about the mechanisms underlying a risk, the better-calibrated one's judgment is about the various risks one faces (Gigerenzer et al., 2007; Siegrist & Arvai, 2020). While when addressing social acceptance issues, one cannot rely solely on showering the population with facts and figures (e.g., Wolsink, 2018b), factual information may help to address some of people's concerns, which may make individuals more positive about an energy project. Most importantly, *Paper 3* shows that better understanding social acceptance issues by involving affect and emotions appears to be essential, as these measures are more revealing than self-reported attitudes. This finding supports the call to consider both affective and cognitive factors when studying social acceptance of energy technologies and more generally energy-related behaviors (e.g., Brosch et al., 2014; Cousse et al., 2020; Russell & Firestone, 2021).

6.2 Practical contributions

The three papers that make up this dissertation offer insights into different practical issues related to the implementation of wind, solar, and geothermal energy projects. Of these, the major ones are discussed below.

In general, it transpires from the three papers that affect plays a significant role in people's perceptions of energy technologies, and more specifically, in the local acceptance of energy projects. While the economic, technical, and cognitive aspects of social

acceptance (e.g., financial incentives) appear to have already been taken into account by practitioners, the latter still sometimes come to the conclusion that people are being irrational or overacting when they exhibit negative emotions towards energy projects, and thus they sometimes tend to respond ineffectively (Perlaviciute et al., 2018). The three papers indicate avenues to both policymakers and project developers for building more effective communication strategies. These take into account the emotional component of energy technologies, thereby reconceptualizing the “purely rational actor” approach to interaction with the population as one that also incorporates the public’s emotions. Specifically, the studies highlight to policymakers and project developers that affect plays a crucial role in people’s perceptions of energy projects. As such, being mindful of negative emotions and bolstering positive ones should also be goals to be pursued at an early stage in communication strategies aimed at helping implement renewable energy projects.

In terms of the individual papers, *Paper 1* highlights that policymakers and project developers who seek the successful implementation of wind power projects should more carefully attend to the silent part of the population who may or may not have an opinion about a project (Gross, 2007), but who are in any case not vocal about it. Not only has research highlighted that there is a gap between the generally positive perceptions about wind energy compared to greater opposition at the local level (e.g., Wüstenhagen et al., 2007), but experience with planned wind energy projects shows that even when the community acceptance is initially high at the local level, it is not guaranteed to endure (TDG, 2020). It thus appears to be crucial to find pathways to avoid a decline in local acceptance until a project is more fully accepted by a population. While strong supporters and opponents may have definite opinions about wind energy projects, opponents and supporters with milder opinions may change their mind throughout the process of implementation, which can take several years. By only focusing on vocal opponents, policymakers and project developers may miss the opportunity to strengthen support among those who could make a difference. Instead, the former should find ways to tailor their communication towards that part of the population who may change their mind. In revealing that different associations are evoked by strong and mild opponents in relation to wind energy (e.g., related to the perceived risks and benefits of the technology) as well as different affective reactions, the study suggests ways that practitioners could approach these two groups differently (see *Paper 1* for more details).

Paper 2 highlights to policymakers and project developers who are looking to deploy solar energy that there exists the risk that any technology, if deployed on a large scale, might face resistance, even if public attitudes are initially overwhelmingly positive. As such, through showing that a stronger preference for solar energy decreases to a similar level as that for wind energy when comparing installations of similar sizes, the study highlights to policymakers that solar energy installations may not be easily scaled up from a social acceptance perspective. Specifically, policymakers who hope that by avoiding wind energy and prioritizing solar energy (Hochstrasser, 2018), they can avoid controversy, may in fact find that they encounter similar issues with large-scale solar, or fail to meet the renewable energy targets defined in their national energy policies. Instead, policymakers are advised to remain well aware of the need to consider social acceptance issues related to all energy technologies, and to think about how to diversify the energy mix to mitigate the risk of opposition. Additionally, through revealing that affect plays an especially important role in forming people's attitudes in the case of large-scale energy installations, *Paper 2* suggests to policymakers and project developers that they may need to increasingly attend to the emotions elicited by energy infrastructures among the population during their development. Debates concerning the implementation of energy projects may indeed become increasingly emotionally loaded as the size of projects and the general deployment of renewable energy projects increase.

Paper 3 provides insights for project developers and policymakers who are looking to deploy shallow and deep geothermal projects. First, it demonstrates that for a relatively unknown technology such as geothermal energy, informing the population about the technology, including its risks, can increase positive affect. However, such information campaigns should be implemented at an early stage, before the public forms strong feelings about the technology. When strong feelings have already been formed, opinions tend to become polarized, hindering constructive communication between stakeholders (Devine-Wright, 2007). Further, *Paper 3* reveals that project developers and policymakers who are looking to deploy deep geothermal projects should stress the benefits of geothermal energy in terms of energy independence and the contribution to phasing out of fossil fuels or nuclear energy, as the value of these benefits decreases as individuals learn about seismic risk and its consequences. Also important is that developers of shallow geothermal projects should emphasize the depth of their projects, as this appears to be a key element in making

people feel more positive about such projects. Further, the study highlights that making information about seismic risk more negative – such as often occurs in the media, or by oppositional party-driven movements – has a negative impact on perceptions about the technology. Policymakers and project developers should thus pay close attention at an early stage to media depictions of the technology to best address any fears and concerns that may arise (see Stauffacher et al., 2015).

6.3 Overall limitations and future research

Although comprehensive research designs based on recognized empirical methods were applied in this thesis that led to relevant findings about the acceptance of renewables, this doctoral thesis is subject to specific limitations that suggest avenues for future research.

One general limitation is the narrow geographical context of the three papers, namely the choice of Switzerland as the setting. Public perception and the acceptance of energy technologies are, to some extent, influenced by a country's geographical and political context. The empirical context of the research for the thesis involves a small and densely populated country with a very specific political regime (i.e., a direct democracy), a low density of solar and wind parks, and, as yet no operational deep geothermal power plants. As such, while Switzerland is similar in various aspects to other countries that are pursuing a transition to a low-carbon energy system, the replication of the studies in regions with different contexts could provide interesting additional insights.

Another limitation which concerns all three papers is the use of stated preference methods in the analysis. In order to obtain a representative view of the Swiss population in relation to their perceptions of wind, solar, and geothermal energy, hypothetical scenarios were chosen to examine preferences. While obtaining a representative view is important and lead to valuable insights, the public's response to hypothetical scenarios is assumed to be only indicative of their likely assessment of specific actual projects that are of direct relevance to them. Related to this limitation, in *Papers 1* and *2* the local acceptance of wind and solar power projects was measured by asking respondents how concerned they would be if an energy installation were built close to their home, or another place they felt close to, thus local concern was used as a proxy for (a lack of) social acceptance at the local level. The former approach was chosen because I was interested in the early stages of preference

formation. The cross-sectional design of these studies, and indeed, of most studies on social acceptance, does not allow for the assessment of whether and how much such concern actually translates into active opposition. Future research could take a longitudinal approach to assessing local acceptance by measuring responses to projects that are progressing through different planning stages, and building up on this work with a qualitative approach such as semi-structured interviews or focus groups. One challenge to implementing such an approach is dealing with inherently smaller sample sizes.

The cross-sectional nature of the surveys used in this thesis creates several other limitations. First, the process of data collection was subcontracted to market research companies. Since these companies generate answers by inviting their panel members to participate in a survey via email, non-response and self-selection bias could not be excluded (Groves, 2006). Nonetheless, self-selection bias was mitigated by only mentioning that the surveys investigated “new energy solutions” instead of providing specific details about the nature of the surveys. Another bias researchers often have to face is a social desirability bias (Diekmann, 2017). The latter relates to the penchant of people to answer questions in a way that could be seen as favorable by others, which can affect the survey results (Diekmann, 2017). Social-desirability and self-reported biases may be avoided by applying indirect questioning such as conjoint methods (Gustafsson et al., 2013).

Another general limitation of this thesis pertains to the measurement of affect and emotions, which involved using self-reporting. Most researchers who study emotions measure them through analyzing one or more of the three specific elements: (1) subjective experience (i.e., labelling, or rating feelings), (2) physiological changes in the brain and body (i.e., sweating palms, or a racing heartbeat), (3) behavioral or expressive responses (Sánchez-Pantoja et al., 2018, p. 231). However, convergence across measures of emotion is limited, reflecting the level of complexity of measuring this phenomenon (Cacioppo et al., 2000). Due to this complexity, there currently is no “gold standard” measure of emotions (Mauss & Robinson, 2009). Experimental, physiological, and behavioral measures are equally relevant for understanding emotional perceptions and reactions, and these cannot be assumed to be interchangeable or exclusionary (Mauss & Robinson, 2009; Sánchez-Pantoja et al., 2018). In the context of this thesis, a mixed-methods approach was initially planned. Based on this approach, interviews followed by experiments employing physiological measures were conducted with approximately 30 bachelor’s and master’s

students in the Behavioral Lab of the University of St. Gallen. While the interviews allowed me to carefully select the pictures used as stimuli in *Paper 2*, the physiological measurements turned out to be poorly adaptable to the research questions, as no significant physiological reactions could be detected in response to them. This supports the statements included above that all methods of the measurements of emotions may be equally relevant, and those may be selected which are most appropriate to the research questions. Nonetheless, it would be insightful to measure affective reactions to energy projects with the Implicit Association Test (IAT) (Karpinski & Hilton, 2001) or physiological measures, if the stimuli and population sample (the more relevant the topic to the population, the better) allows it.

Lastly, this thesis investigated the acceptance of the public only and public opinion as part of the socio-political and community acceptance dimensions of the social acceptance triangle. However, the concept of social acceptance of renewables is made up of mutually influencing processes at the three levels (community, socio-political, market) and also involves different actors (project developers, policymakers, consumers) who are active at different levels (Wolsink, 2018b). As per Wolsink (2018b), for understanding social acceptance we need studies that cover all three levels, and which, in particular, address their interconnections. Given the latter, future research could apply the multiple levels holistically by investigating processes of social acceptance as they move between policy, market, societal and community levels. More concretely, future studies could, for example, investigate how different policies at the socio-political level can impact market and community acceptance, or how the different emotions elicited by energy projects at the community level may influence market and socio-political acceptance.

6.4 Overall conclusion

Taken together, the findings presented here and in the related papers show that, as the deployment of renewables significantly increases to help mitigating the effect of climate change, policymakers and project developers may increasingly have to attend to the affect and emotions elicited by energy infrastructures among the population during the different phases of development of energy projects, and improve their communication based on the

better comprehension of these emotions. Attempts by policymakers or project developers to convey rational knowledge about the benefits of renewable energy projects may not lead to the intended behavioral outcomes unless emotional components are taken into account. This thesis has shown that not only do affect and emotions play a significant role in people's perceptions of renewable energy projects, but that measuring the latter through affective variables can generate crucial insight into how different segments of the population perceive energy projects. Further, it has highlighted that approaches to social acceptance of renewables should be tailored to: (1) the type of supporters and opponents (mild versus strong), while giving more voice to the "silent majority", (2) the affect and emotions elicited by the energy sources and specific projects, (3) the size of the energy installation, and (4) the technological maturity of the technology (i.e., deep geothermal versus solar, wind, or shallow geothermal). These insights provide project developers, policymakers, and researchers with a basis for segmenting target groups in relation to managing the process of increasing social acceptance of renewable energy projects. Achieving this goal may make the implementation of renewable energy projects smoother and more successful, and generally contribute to achieving the goals of the Swiss Energy Strategy 2050 and the Paris agreement.

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Paper I

Mixed feelings on wind energy: Affective imagery and local concern driving social acceptance in Switzerland¹

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Abstract

Several countries are witnessing increasing levels of local opposition to wind energy projects. This is in contrast to opinion polls often showing that a large majority of the population is supportive of low-carbon policies, including deployment of wind energy. At the same time, project developers and policymakers are realising that social acceptance has an emotional component, but struggle to find ways to manage this phenomenon. We surveyed a representative sample of Swiss residents (n = 1111) using affective imagery, asking respondents to list their spontaneous associations with wind power and provide an affective evaluation of each association. We find a strong correlation between the affective imagery and respondents' likelihood to express concern about local wind projects, suggesting that affect matters in the formation of attitudes towards local wind energy projects. An in-depth analysis of the sequencing of affective imagery highlights that mild opponents have conflicting feelings about wind energy, and that "second thoughts" appear to tip the balance towards opposition for them. The study further reveals that important differences exist between mild and strong opponents, providing a basis for the segmentation of target groups in managing processes of social acceptance.

Keywords: Affect, Emotions, Segmentation, Social acceptance, Wind energy

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1. Introduction

Electricity supply is one of the principal contributors of CO₂ emissions, accounting for 41% of global emissions (IEA, 2019). In various countries, policy measures are introduced to promote the use of renewable energy and to reduce dependency on fossil fuels and nuclear energy. This transition towards a cleaner energy future is also facilitated by the technology learning curves of renewable energies. Wind power, in particular, is now among the most cost-competitive sources of electricity (IRENA, 2019; Lazard, 2019; BNEF, 2019a) and accounts for more than half of new renewable energy capacity investment worldwide (BNEF, 2019b). And yet, the diffusion of wind power has recently slowed down in key markets due to social acceptance issues (Cross, 2018; Buck, 2019). While acceptance of renewable energies, and wind power especially, tends to be high on a general level (Gamma et al., 2017; Volken et al., 2018; European Commission, 2019; Dubois et al., 2019), local implementation often faces opposition. Indeed, a discrepancy between general acceptance and local acceptance of wind power has been found in many countries, including Canada, Finland, the United States and the United Kingdom (Bell et al., 2013; Clean Energy Canada, 2016; Larson & Krannich, 2016; Janhunen et al., 2018). This emphasises the need to gain a more nuanced understanding of the dynamic processes that lead to acceptance or opposition on the local or community level (e.g., Walker & Baxter 2017; Walker et al., 2018; Wolsink, 2018).

One factor that has recently been gaining increasing attention is the affective component of social acceptance. From early work on nuclear power (Peters & Slovic, 1996), research has lately started to include a focus on renewables (Truelove, 2012; Sütterlin & Siegrist, 2017). Solar power has been shown to elicit highly positive imagery (Sütterlin & Siegrist, 2017), while wind power projects have, in some cases, faced strong negative emotions (Cass & Walker, 2009; Perlaviciute et al., 2018). Dual-process theories of decision making (Kahneman, 2011) suggest that affective and cognitive factors interact in complex ways (Slovic et al., 2007). Eliciting people's spontaneous associations to wind projects may therefore be a promising route towards gaining a deeper understanding of social acceptance issues on the local level. The present paper embarks on this route by using affective imagery

(Slovic et al., 1998), a two-step methodology to uncover emotional influences in the process of attitude formation. In a first step, respondents are asked to list up to five spontaneous associations that come to mind with regard to a stimulus, in this case, wind energy. In a second step, they are asked to rate these associations on an affective scale, indicating whether these images elicit positive or negative feelings.

Apart from investigating affective imagery, this paper also explores how such imagery is linked to local concern about wind energy. We use local concern as a proxy for (lack of) social acceptance on the local level because we are interested in the early stages of preference formation. Social acceptance is a dynamic process, where weak initial attitudes tend to become stronger over time as a planned project gets specified and ultimately implemented (Druckman & Lupia, 2000; Walker et al., 2010; Wolsink, 2018). While, from an overall climate change mitigation perspective, the variable of interest is active support of, or opposition to a project (Schweizer-Ries et al., 2008), once this materialises, it is usually too late to intervene. Investigating concerns as a potential precursor of local opposition provides project developers with an opportunity to shape social acceptance processes as they unfold. This is important as previous research has highlighted that general attitude is a strong predictor of local acceptance (Walter, 2014).

On an individual level, preference formation is not necessarily a linear process. While some parts of the population tend to have strongly positive or negative feelings early on, there is often a silent majority with less pronounced initial views (King & Anderson, 1971; Leitch & Davenport, 2006; Motosu & Maruyama, 2016). Investigating the decision process of these mild supporters or mild opponents can be crucial for forecasting local acceptance, similar to how political scientists interested in forecasting election outcomes tend to focus on swing voters e.g. (Mayer, 2007). By eliciting up to five spontaneous associations, our dataset gives us a unique opportunity to explore whether the sequence of positive and negative affective evaluations matters in tipping the balance from support to opposition.

Taken together, the objectives of this research are to (a) analyse the affective imagery elicited by wind power, (b) explore links between affective imagery and local concern, and (c) investigate whether the sequence of negative and positive affective evaluations can shed light on the preference formation process of supporters and opponents of wind energy

projects. The findings will help policymakers and project developers craft new strategies for managing processes of social acceptance on the local level and thus support the implementation of low-carbon policies.

The remainder of this article is structured as follows: Section 2 outlines the literature review and research questions. Section 3 presents the sample used in the analysis and illustrates the research design. Section 4 describes the results of the study according to the research questions. Section 5 concludes the paper by reviewing the main findings, drawing policy implications and outlining recommendations for further research.

2. Literature Review

2.1 Social acceptance of renewable energy

Research on public perceptions of renewable energy (RE) projects dates back to the 1980s (Bosley & Bosley, 1988). Research interest started to increase a decade ago following the publication of an Energy Policy special issue edited by Wüstenhagen et al. (2007) in which three dimensions of social acceptance were identified: socio-political, market and community acceptance (Wüstenhagen et al., 2007). Despite high levels of approval for wind energy at the national level (Tabi & Wüstenhagen, 2017; Cousse & Wüstenhagen, 2019), reflecting the acceptance level at the socio-political level, wind energy projects face a number of acceptance-related issues at the local level (i.e., community level) (Braunholtz, 2003; Strachan & Lal, 2004; Warren et al., 2005; Ellis & Ferraro, 2016).

In an attempt to explain this gap, past studies have explored the concept of NIMBYism, which suggests that support for renewable energy technologies may be dependent on not being sited in people's vicinity. However, this concept has been criticised for offering an oversimplified explanation for the low level of community acceptance (Devine-Wright, 2005; Devine-Wright, 2007; Wüstenhagen et al., 2007; Walker & Devine-Wright, 2008; Walker et al., 2010), and some have found evidence for an opposite effect, namely a PIMBY (Please In My Backyard) reaction (Burningham, 2000; van der Loo, 2001;

Braunholtz, 2003; Pasqualetti, 2004; Wolsink, 2006; Wolsink, 2007; van der Horst, 2007; Langer et al., 2016; Rand & Hoen, 2017;). Proximity to a proposed or existing wind energy project appears to be an important factor to consider (Rand & Hoen, 2017) for a variety of reasons including noise and aesthetic concerns (Pasqualetti, 2001). Other studies have also highlighted that noise disturbance is moderated by visibility of a wind park (Pedersen & Larsman, 2008; Schaffer et al., 2019). Other issues such as procedural and distributive justice, have shown to also be crucial in understanding social acceptance of wind power (Cowell et al., 2011; Walker & Baxter, 2017).

According to Wolsink (2007) or Dimitropoulos and Kontoleon (2009), in the context of social acceptance of wind energy, the main institutional factors are procedural justice, namely the extent to which different stakeholders are involved in the decision-making process and distributional justice, that is, whether the benefits and costs of the project are fairly distributed. In this regard, Walker and Baxter (2017) have, for example, found that both the fair distribution and the amount of local benefits are important predictors of project support. More recently, a study from Vuichard et al. (2019) highlighted that a local resource tax which benefits an entire community is preferred over individual financial participation models.

Other studies have found that familiarity with energy technologies can increase acceptance (Wolsink, 1994; Krohn & Damborg, 1999; Baxter et al., 2013; Simcock et al., 2016). This change in acceptance over time have been depicted as a U-shaped curve (Wolsink, 1994). The model states that public attitudes change from very positive before a project is announced, to negative during the planning and construction phase, to positive again after the project has been built (Wolsink, 1994). While the link between familiarity and acceptance has been clearly identified (e.g., van der Horst, 2007; Tabi & Wüstenhagen, 2017; Volken et al., 2018), knowledge about how familiarity influences affect elicited by energy technologies is limited.

2.2 Affective imagery and energy technologies

Zajonc (1980) argued that affective reactions to a stimulus happen automatically and guide following judgment. In fact, a large and growing body of literature has confirmed that affect plays a key role in decision-making (e.g., Johnson & Tversky, 1983; Epstein, 1994; Peters & Slovic, 1996;). However, while a large body of research has investigated the cognitive underpinnings of energy-related preferences (e.g., Poortinga et al., 2005; Wüstenhagen et al., 2007; Greenberg, 2009; Whithfield et al., 2009; Ansolabehere & Konisky, 2009; Tabi & Wüstenhagen, 2017; Vuichard et al., 2019), a smaller body of research has investigated affective factors (Truelove, 2012; Visschers & Siegrist, 2014; Sütterlin & Siegrist, 2017; Jobin & Siegrist, 2018; Jobin et al., 2019).

Psychologists have used word associations techniques, such as the ones used in affective imagery, for a long time (Galton, 1879; Hollway & Jefferson, 2008; Joffe & Elsey, 2014). Affective imagery uses word associations to identify the positive and negative associations elicited by an object (Leiserowitz, 2006). As they are spontaneous, the associations provided tend to avoid self-censorship and social desirability bias (Leiserowitz & Smith, 2017). Further, when affective imagery is carried out with a representative sample, the results are generalisable, and can thus be quantitatively correlated to different sociodemographic variables or attitudes (Leiserowitz & Smith, 2017). Scientists have used affective imagery in a wide range of research domains such as gene technology (Connor & Siegrist, 2011), risk perception of global warming (Leiserowitz, 2005; Leiserowitz, 2006; Leiserowitz & Smith, 2017), nuclear power (Peters & Slovic, 1996) or smoking (Benthin et al., 1995).

Specifically, in Slovic et al. (1991), the authors found that affective imagery predicted public risk perceptions of nuclear energy and correlated strongly with intended voting behaviour and opposition to new power plant construction. Jobin and Siegrist (2019) observed that affect was a significant predictor of energy portfolio preferences as individuals' affective reactions to energy technologies guided the percentage of the respective technology included in their preferred portfolio. Further, Truelove (2012), found that her affective model was significant in predicting local acceptance (i.e., project implementation close to one's home), but not general acceptance (i.e., increased reliance of

the country on wind energy). She also explored affective imagery elicited by wind energy and found that associations related to ‘windmills’ and ‘turbines’ were clearly dominant and that overall, associations to wind energy were positive. However, the study did not provide an exhaustive presentation of associations elicited by wind energy. Further, the sample used was small and not representative of the population. Visschers and Siegrist (2014) looked into the effect of positive and negative emotions on acceptance of different energy sources (i.e., wind, solar, hydro, nuclear, gas). As one may have expected, the results highlighted that, in general, positive emotions significantly increase acceptance for any energy source. Further, Huijts et al. (2012) reported in a review on psychological factors influencing sustainable energy technology acceptance that affect, together with perceived costs and benefits, influences attitudes.

While these results give us an interesting starting point, the following limitations have been identified. First, while previous research found that affect is significantly correlated with acceptance, there is a lack of insights about how the affect elicited by wind energy vary between individuals’ characteristics. Second, previous analysis using affective imagery aggregated all the associations provided by the respondents and did not look at the sequence in which they were given.⁴ As such, the dynamics between the different and potentially conflicting associations about energy sources and their respective affective evaluations have not been analysed so far. However, the nature of these associations, their affective evaluations, as well as the order in which they are mentioned, may be essential to gain better insights on how people form their preferences.

2.3 Query theory, preference construction and affective evaluations

Psychologists and behavioural economists agree that most preferences are constructed, rather than innate. Query theory (Johnson et al., 2007; Weber & Johnson, 2011) is a psychological process model of preference construction, which assumes that options offered to an individual are evaluated by a sequence of queries that recover various aspects

⁴ For example, if the associations of a respondent were “wind turbine” (sequence 1), “environmentally friendly” (sequence 2), “noise” (sequence 3), “ugly” (sequence 3), “green” (sequence 4), “Germany” (sequence 5”), these five associations were aggregated without taking into account in which sequence they occurred.

of possibly relevant knowledge about the option selected (Weber et al., 2011). Query theory asks respondents to list thoughts that come to their mind as they make a decision, to better understand the process underlying the latter. In its simplest form, query theory holds that people use their past experience for evidence supporting different choice options and that the first query is more important to the final decision than the subsequent ones (Weber & Johnson, 2011). As such, a key prediction of query theory is that the order of queries matters and that the first query produces a richer set of answers than the subsequent ones. In other words, query theory predicts that reasons for choosing the preferred option will be queried first (Weber & Johnson, 2011).

To the best of our knowledge, no studies using affective imagery in the energy context have so far looked into the sequence in which different associations were provided by the participants and the possible incidence of the sequencing on decision-making or preferences. According to query theory, one could expect that the order in which the images are provided matters in preference formation for energy sources. Thus, the first thought provided may have a more prominent weight on preference concerning the implementation of wind energy projects than the following thoughts. Accordingly, we looked into the different roles of first versus “second thoughts” provided by the participants concerning social acceptance of wind energy and we defined “second thoughts” as any thoughts provided by respondents after the very first thought indicated.

2.4 Research questions

This study investigated the affective imagery elicited by wind power and its effect on local concern for wind energy projects in order to answer the following three research questions:

1. *What affective imagery does wind power elicit, and how does it vary depending on individuals' characteristics?*
2. *What is the relationship between affect elicited by wind energy and local concern for wind energy projects, and how do associations vary between opponents and supporters?*
3. *How do "second thoughts" elicited by wind power differ from the first thought?*

3. Methods

3.1 Sample

The data for this study were collected between March and April 2019 through a large-scale survey. Participants of our study were drawn from an actively recruited Swiss online consumer panel (N = 100,000) operated by an experienced market research agency.⁵ A representative sample of the adult population from the German- and French-speaking parts of Switzerland was obtained by stratifying the population by gender, education, age, political orientation and geographical regions. Further, 19% of the respondents reported living in a city centre, 12% in the suburbs, 23% in an agglomeration and 46% in rural areas. Moreover, we boosted the sample (n = 180) with respondents living close to⁶ existing or planned wind energy projects based on data from the Swiss Federal Office of Energy, in order to get a balance between national representativeness and a sufficient share of respondents living in areas that are affected by wind energy. In total, 187 of the respondents in the sample live close to a planned wind park while 87 live close to an existing one. The final sample size is made of 1111 respondents,⁷ excluding incomplete responses, people failing to pass an attention test and those with regular response patterns (flatliners).⁸ The

⁵ While opt-in panels are made up of a self-selected sample of volunteers, Intervista's actively recruited panel comes close to a probability sample of the Swiss voting population.

⁶ "close to" refers to having a place of residence in the same postal code as the wind energy project.

⁷ Appendix A includes the sample distribution. Since German or French is the main language for 85% of the Swiss population and only 8% of the Swiss population live in the Italian-speaking region of Ticino [90], we limited the survey to the two dominant languages for research efficiency. Also, the boost of the sample for respondents living close to existing or planned wind parks led to having a slight over-representation of French-speaking respondents as detailed in Appendix A.

⁸ The response rate was 98.63% while the completion rate reached 81.65%.

respondents were remunerated the equivalent of 8 Swiss francs in gift cards for taking part in the study.

3.2 Measures

3.2.1 Affective imagery

Affective imagery consists of both cognitive contents, such as images or thoughts (i.e. imagery) and affective evaluation (i.e. affect) (Leiserowitz, 2006). The images or thoughts were collected using the method of continued word associations (Slovic et al., 1991; Peters & Slovic, 1996). Respondents were asked, “What are the first thoughts or images that come to your mind when you think of wind energy?”. In response to this question, respondents could provide either single word associations (e.g., “bird”) or brief narrative statements (e.g. “wind turbines on hills that can be seen from afar”) (Leiserowitz, 2006). In this study, participants had to provide at least one and a maximum of five thoughts.⁹ The respondents subsequently evaluated each of their associations on a seven-point affect scale from 1 (“very negative”) to 7 (“very positive”).¹⁰ The association evaluation scale was calculated by taking the mean of the associations’ evaluations participants provided with higher scores indicating more positive evaluations.

In Section 4.3.2, to investigate the importance of first versus second thoughts (i.e. associations), we created a variable which indicates in which sequence respondents provided negative and positive thoughts. For this purpose, we compared the evaluation of the first association provided to the average evaluation of all subsequent associations. For example, if a respondent provided three associations in the following order (renewable = 6.0; bird = 3.0; noise = 1.0), then we compared the evaluation 6.0 (first thought), to the evaluation 2.0 (average of second and third thoughts). The respondents were further

⁹ While Truelove (2012) compelled respondents to give five images, and Sütterlin and Siegrist (2017) only asked for one, we opted for a middle solution to avoid meaningless answers while allowing for richness in the data.

¹⁰ The respondents only saw the reference points “very negative” and “very positive” and not the respective numbers.

categorized in two different groups: 1 = first association negative, 2 = first association positive.¹¹

A large dataset of 2890 associations was produced using affective imagery from the 1111 respondents. Using a qualitative analysis, one author developed the coding system and categorised all the associations to the categories. In a second step, a second author coded all associations again, independently from the first author. Inter-rater reliability achieved satisfactory significance (82%) between the two coders. If an association was not categorised to the same category by both authors, a discussion ensued to find a common and adequate solution. Further, if no common nor adequate solution could be found, a new category was created, and all associations were re-coded using the revised coding system. We repeated this procedure until all associations were assigned to one category by common accord. Through this procedure, the different images were classified into 50 distinct categories, which can be found in Appendix G. The associations were categorised according to the theme they were related to and not according to their valence. This means that words such as “ecological” or “harmful for the environment” can be found under the same category “Environment & Ecology”. To reduce interpretation bias to a minimum, we categorised responses in more than one category if the image could either be interpreted in different ways or if more than one image was expressed at a time.

3.2.2 Socio-demographic and control variables

Socio-demographic variables were also collected (political orientation, gender, education, age and language). With regards to political orientation, participants could select between one of the seven major parties in Switzerland or the category “others”. Switzerland's political system is particular as its federal government includes all major parties, but the largest party, the national-conservative Swiss people's party (SVP), often opposes decisions on which other parties commonly agree on, including regarding the energy transition and also specifically regarding wind energy projects (Herrmann &

¹¹ For this measure, respondents were excluded based on the following criteria: provided only one association (n=352) and had neutral evaluations for their first association or as the average evaluation of subsequent associations (n = 127).

Städler, 2014; RTS, 2017; Quiquerez, 2017). To reflect this cleavage, we defined the variable ‘political orientation’ as a dummy, where 0 indicates that the respondent indicated support for SVP, and 1 support for any other party as in a previous study by Tabi and Wüstenhagen (2017).

We also controlled for awareness of a planned wind park close to one’s home. We measured it by asking “Is a wind park planned to be built close to your home (less than 5 km)?” (Yes; No; I do not know). In a next step, a binary variable was constructed (0=No or I do not know; 1 = Yes). The operationalisation of this variable is based on the appraisal theory of emotions which holds that emotions reflect the integration of the relevance of an event or object in the context of a person’s concerns, goals, needs, and values (Brosch et al., 2014). As such, if one is aware that a wind park may be planned close to his or her residence, he or she may have a different reaction to wind energy and its implementation than someone who is not aware of it.

Further, we controlled for familiarity with wind energy. This variable was measured by asking respondents to evaluate the following statement: “I am familiar with seeing wind turbines in my immediate environment”. The answer scale ranges from I very much disagree to I very much agree (4-point).

3.2.3 Local concern

As a proxy to social acceptance, we measured the extent to which respondents would be concerned about having a wind park built close to their home or other places they feel close to. Specifically, local concern was assessed with the following question inspired by Maehr et al. (2015): “I would be concerned if a wind turbine would be built in my neighbourhood or other places, I feel close to”, on a scale from 1 (totally disagree) to 5 (totally agree). Respondents could also choose the option I do not know. Respondents who selected I do not know were removed from the sample (N = 30). Operationalisation of the variable was done as follows: respondents were categorised as opponents if they selected points 4 or 5, as supporters if they selected points 1 or 2 and as indifferent if they selected point 3 on the 5-pt scale. For some parts of the study, the sample was further divided between strong supporters (1), mild supporters (2), indifferent (3), mild opponents (4), strong opponents

(5). While “local concern” does not measure actual opposition or support, it allows to investigate concerns as a potential precursor of local opposition.

3.3 Procedure

The survey data was analysed using SPSS. After categorising the associations, we used simple relative frequency and mean average to explore the affective imagery elicited throughout the sample group. In a second step, we used one-way ANOVAs to investigate how the affective evaluations varied based on the individuals’ characteristics. In a third step, we used chi-squared tests to explore how the relative frequency of the associations previously categorized, varied between respondents. In a fourth step, a linear regression was run to measure the relationship between affect and local concern while controlling for important variables such as political orientation or rural versus urban environments. Next, as the regression established that affect was significantly related to local concern, we investigated how the associations about wind energy varied between supporters and opponents using relative frequency. We further compared how overall affective evaluations of the associations elicited by wind energy differed between strong or mild opponents and supporters. Finally, to investigate the importance of first thought versus second thoughts elicited by wind power, we used one-way ANOVAs.

4. Results

4.1 Affective imagery elicited by wind power

4.1.1 General overview of affective imagery elicited by wind power

The analysis identified 50 distinctive categories of affective images associated with wind energy. The definition of each category can be found in Appendix G. Mean affect scores indicate that respondents, as a whole, perceive wind energy as something moderately positive ($N=1111$, $M_{\text{overall}}=4.526$, $SD=1.832$; $\text{min}=1$; $\text{max}=7$). Overall, most responses

(51%) were positive, while 38% were negative, and only 11% neutral.¹² The twenty main categories, based on their relative frequency, are pictured in Figure. 1.¹³

Dominant negative associations are linked to landscape, noise or wildlife ($M_{\text{landscape}} = 2.73$, $SD = 1.70$; $M_{\text{noise}} = 2.38$, $SD = 1.47$; $M_{\text{wildlife}} = 1.81$, $SD = 1.15$). More specifically, images related to landscape, noise and wildlife make up 19% of people's affective imagery related to wind energy. These results indicate that on average, the impact of wind turbines on the landscape, wildlife and concerns about potential noise disturbance are the most salient images among the Swiss public (e.g., "Difficult to integrate into the landscape and noisy").

Dominant positive associations are linked to the ecology, power production and wind ($M_{\text{ecology}} = 5.93$, $SD = 1.77$; $M_{\text{power production}} = 6.23$, $SD = 1.42$; $M_{\text{wind}} = 5.70$, $SD = 1.41$). This potentially highlights that positive associations about wind energy are less concrete than negative ones. Precisely, these images make up 15% of people's affective imagery related to wind energy. Further, the most positive affective imagery is attached to renewable energy ($M_{\text{re}} = 6.77$, $SD = 0.55$), sustainability ($M_{\text{sustainability}} = 6.67$, $SD = 0.84$), air ($M_{\text{air}} = 6.24$, $SD = 1.15$) and clean energy ($M_{\text{clean}} = 6.69$, $SD = 0.66$). Moreover, a contribution to energy independence as one of the potential positive impacts of increased production of domestic wind energy is only mentioned in 0.3% of the images.

¹² "Positive" corresponds to scores above 4, "negative" to scores below 4 while "neutral" to scores of 4.

¹³ The categories "wind turbine" (15% of the associations) and "other" (2% of the associations) were not highlighted in the analysis because of their low symbolic meaning.

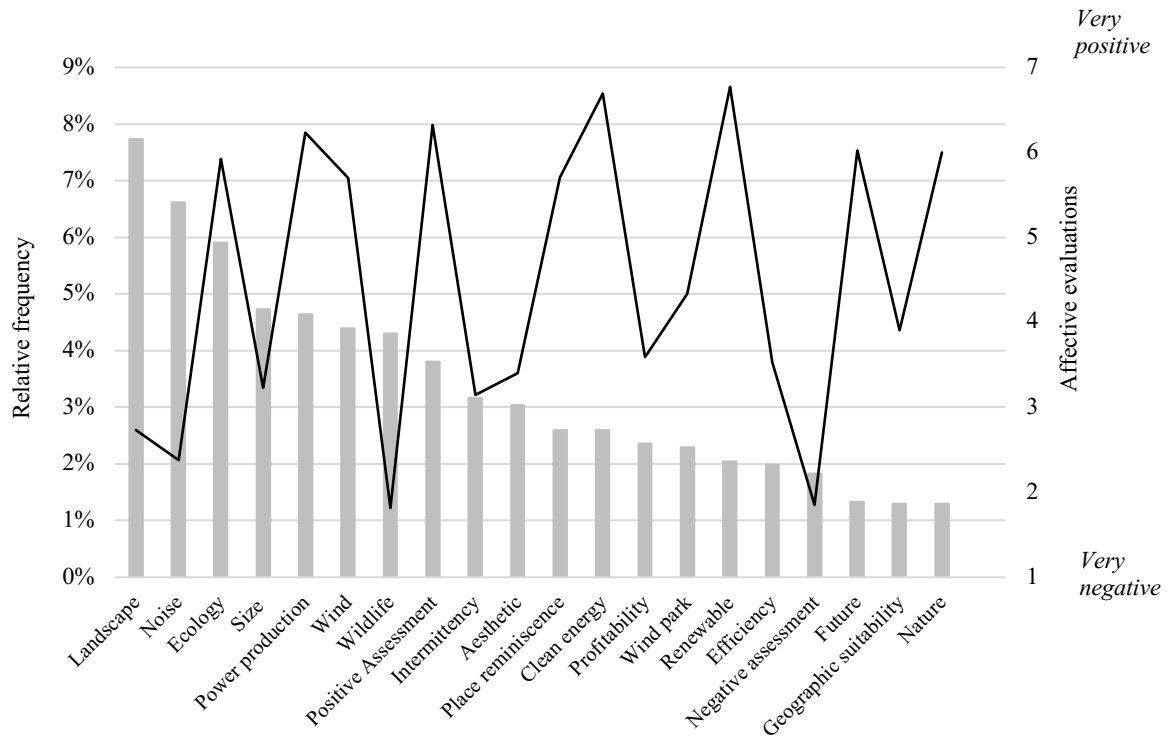


Figure 1: Dominant imagery elicited by the stimulus “wind energy”.

4.1.2 Individuals’ characteristics and affective imagery elicited by wind power

Next, we explored differences in affective imagery elicited by wind power based on individuals’ characteristics: place of residence (rural versus urban), age, gender, political orientation, language, familiarity with wind energy and awareness about a planned wind park close to one’s home. To explore differences in affective imagery, we first looked into variations in affective evaluations (i.e. the evaluation of the associations using a 7-pt affect scale) using t-tests of means and one-way ANOVAs. In a second step, we investigated whether any differences existed in the associations produced by the respondents by comparing the relative frequencies of the categories.

4.1.2.1 Differences in affective evaluations between individuals’ characteristics.

We used t-test of means to analyse how the affective evaluations of the associations elicited by wind power (i.e. affective imagery) vary based on political orientation (0=

national-conservative Swiss people's party (SVP); 1 = other political parties). The results highlight statistically significant differences based on political orientation ($n = 1111$, $F = 29.744$, $df = 1$, $p = 0.000$, $\eta_p^2 = 0.026$).¹⁴ Specifically, supporters of the national conservative party have significantly less positive affective evaluations ($M_0 = 4.029$, $SD_0 = 2.03$, $N_0 = 291$), than other voters ($M_1 = 4.702$, $SD_1 = 1.722$, $N_1 = 820$).

We next applied a 1x4 ANOVA ($n = 1111$, $F = 6.014$, $df = 3$, $p = 0.000$, $\eta_p^2 = 0.016$)¹⁵ to analyse differences between age groups (1 = below 30; 2 = 30–44, 3 = 45–59, 4 = 60 and above). Post-hoc tests applying Games-Howell correction for all four age groups ($p_{12} = 0.003$, $p_{13} = 0.000$, $p_{14} = 0.001$) revealed that respondents under 30 years of age have significantly more positive affective evaluations ($M_1 = 4.976$, $SD_1 = 1.547$, $N_1 = 227$) about wind energy than respondents from the other age groups ($M_2 = 4.476$, $SD_2 = 1.694$, $N_2 = 282$; $M_3 = 4.373$, $SD_3 = 1.934$, $N_3 = 301$; $M_4 = 4.385$, $SD_4 = 1.995$, $N_4 = 301$).

A 1x4 ANOVA was used to measure the variations based on familiarity (1 = very unfamiliar to 4 = very familiar) to wind energy ($n = 1111$, $F = 41.14$, $df = 3$, $p = 0.000$)¹⁶. Post-hoc tests applying Games-Howell correction for all four levels of familiarity ($p_{12} = 0.000$, $p_{13} = 0.000$, $p_{14} = 0.000$) highlight that respondents that are not familiar at all with wind energy, have significantly less positive associations about the technology ($M_1 = 3.988$, $SD_1 = 1.886$, $N_1 = 571$) than respondents who are (rather) familiar with it ($M_2 = 4.867$, $SD_2 = 1.606$, $N_2 = 283$; $M_3 = 5.233$, $SD_3 = 1.531$, $N_3 = 142$; $M_4 = 5.481$, $SD_4 = 1.528$, $N_4 = 115$). We do not find significant differences for the other control variables.

4.1.2.2 Differences in associations elicited by wind power between individuals' characteristics.

We tested differences in the content of associations between individuals using the chi-square test. We find significantly different associations between gender ($\chi^2 = 157.211$, $df = 49$, $p < 0.001$), age group ($\chi^2 = 241.704$, $df = 147$, $p < 0.001$), political orientation ($\chi^2 =$

¹⁴ Levene's test was significant at $p < 0.001$. Welch's ANOVA ($F = 25.46$, $df_1 = 1$, $df_2 = 446.792$, $p < 0.001$).

¹⁵ Levene's test was significant at $p < 0.001$. Welch's ANOVA ($F = 7.388$, $df_1 = 3$, $df_2 = 609.359$, $p < 0.001$).

¹⁶ Levene's test was significant at $p < 0.001$. Welch's ANOVA ($F = 43.147$, $df_1 = 3$, $df_2 = 356.19$, $p < 0.001$).

83.838, $df = 49$, $p = 0.001$), language group ($\chi^2 = 322.200$ $df = 49$, $p < 0.001$) and familiarity with wind energy ($\chi^2 = 243.042$, $df = 147$, $p = 0.001$).

Next, we compared the relative frequency of the main positive and negative categories of associations identified in Section 4.1.1. The results, depicted in Table 1, show that males tend to think more about landscape than women, while the latter tend to focus more on noise than males. We further find that respondents under 30 years of age appear to think about landscape about half as much as those above 60. The older generation also seems to have a greater focus on wildlife than those below 30. On the contrary, those under 30 have more associations related to the environment or the ecology than those above 60. Table 1 also shows that respondents who are very unfamiliar with seeing wind turbines in their immediate environment, think, on average, almost twice as much about issues related to the landscape and have three times as many associations about wildlife than those very familiar with it. Additionally, respondents who are very familiar, have more associations about the power produced from wind turbines than those very unfamiliar. The results further highlight that wind energy elicits about twice more associations about noise among French-speaking respondents than among German-speaking ones.

	Frequency (percentage)							
	Total	Gender		Age group				Political orientation
		Males	Females	<30	30-44	45-59	>60	SVP
Landscape	250 (8%)	153 (9%)	97 (6%)	35 (5%)	60 (8%)	77 (8%)	78 (10%)	70 (9%)
Noise	214 (7%)	91 (5%)	123 (8%)	32 (5%)	48 (6%)	66 (7%)	68 (8%)	63 (8%)
Wildlife	139 (4%)	66 (4%)	73 (5%)	21 (3%)	35 (4%)	39 (4%)	44 (5%)	33 (4%)
Ecology	191 (6%)	97 (6%)	94 (6%)	52 (7%)	47 (6%)	56 (6%)	36 (4%)	39 (5%)
Power production	150 (5%)	90 (5%)	60 (4%)	42 (6%)	33 (4%)	39 (4%)	36 (4%)	22 (3%)
Wind	142 (4%)	75 (4%)	67 (4%)	37 (5%)	41 (5%)	45 (5%)	19 (2%)	35 (4%)
Total number of associations categorized	3231 (100%)	1690 (100%)	1541 (100%)	694 (100%)	798 (100%)	927 (100%)	812 (100%)	788 (100%)

	Frequency (percentage)							Affective evaluation (M, (SD)) Total
	Political orientation	Language group		Familiarity with wind energy				
	Other party	German	French	(1)	(2)	(3)	(4)	
Landscape	180 (7%)	154 (7%)	96 (10%)	145 (9%)	66 (8%)	23 (6%)	16 (5%)	2.73 (1.7)
Noise	151 (6%)	122 (5%)	92 (9%)	122 (7%)	55 (6%)	16 (4%)	21 (7%)	2.38 (1.47)
Wildlife	106 (4%)	104 (5%)	35 (4%)	94 (6%)	29 (3%)	9 (2%)	7 (2%)	1.81 (1.15)
Ecology	152 (6%)	131 (6%)	60 (6%)	91 (5%)	50 (6%)	30 (8%)	20 (6%)	5.93 (1.77)
Power production	128 (5%)	104 (5%)	46 (5%)	66 (4%)	43 (5%)	19 (5%)	22 (7%)	6.23 (1.42)
Wind	107 (4%)	45 (2%)	97 (10%)	66 (4%)	35 (4%)	15 (4%)	26 (8%)	5.7 (1.41)
Total number of associations categorized	2443 (100%)	2232 (100%)	999 (100%)	1684 (100%)	848 (100%)	376 (100%)	323 (100%)	

*Note: To reduce interpretation bias to a minimum, we categorized responses in more than one category if the image could either be interpreted in different ways or if more than one image was expressed at a time. This explains the gap between the total of associations provided (n=2890) and the total of number of associations categorized (n=3231). * “I am familiar with seeing wind turbines in my immediate environment”; The answer scale ranges from 1 very much disagree to 4 very much agree (4-point).*

Table 1: Affective imagery of respondents - gender, age group, political orientation, language group, familiarity with wind energy

4.2 Affective imagery and local concern

4.2.1 Affective evaluations and local concern

We used a multiple regression model to explore the relationship between affect and local concern while controlling for socio-demographic variables, place of residence (rural versus urban), familiarity with wind energy and awareness about planned wind energy projects in one's neighbourhood.

The results (see Table 2) highlight that affect is significantly correlated with local concern. The more positive someone feels about wind energy, the lower the local concern. The results further show that political orientation, familiarity with wind energy and language regions (German- versus French-speaking) are highly correlated with local concern for wind energy. Specifically, we find that (1) voters from the national conservative party, (2) individuals self-reported as less familiar with wind energy and (3) respondents

from the French-speaking region of Switzerland have a higher local concern about the implementation of a wind energy project close to their homes or other places they feel close to.

Independent variables	Local concern				
	B	SE	Beta	p-values	95% CI
Constant	5.036	0.231		0.000	[4.583, 5.489]
Affective evaluation (average)	-0.339	0.022	-0.417	0.000	[-0.383, -0.295]
Place of residence	-0.01	0.034	-0.007	0.774	[-0.076, 0.056]
Political orientation	-0.34	0.088	-0.1	0.000	[-0.513, -0.167]
Gender	0.033	0.077	0.011	0.663	[-0.117, 0.184]
Education level	-0.111	0.08	-0.037	0.167	[-0.268, 0.047]
Familiarity with wind energy	-0.217	0.04	-0.148	0.000	[-0.297, -0.138]
Awareness planned wind project	-0.009	0.131	-0.002	0.944	[-0.266, 0.248]
Age group	0.021	0.036	0.015	0.561	[-0.049, 0.091]
Language regions	0.579	0.084	0.179	0.000	[0.413, 0.744]
R ² adjusted	0.281				
F	47.805			0.000	

Table 2: Multiple regression analysis on the level of local concern for wind energy projects

4.2.2 Differences in associations between supporters and opponents

While the results in Section 4.2.1 highlight a significant correlation between affect and local concern, they do not reveal how the associations elicited by wind energy vary between supporters and opponents. To gain insights on the latter, we divided our sample between strong supporters ($n = 223$), mild supporters ($n = 241$), indifferent ($n = 185$), mild opponents ($n = 172$), strong opponents ($n = 290$). This distinction between different types of supporters or opponents is important as recent research has highlighted that the silent part of the population may be a key component in social acceptance of wind energy (Rand & Hoen, 2017). The results are depicted in Figure 2. In the left column, pie charts highlight the respective shares of positive, neutral and negative associations for each sub-group. In the right column, bar charts show the five most dominant categories (highest relative frequency) for each group along with the affective evaluations.

The results first show that while positive associations make up 76% of the total share of associations elicited among strong supporters, this share falls to 62% for mild supporters, 55% for individuals who are indifferent, 45% for mild opponents and 27% for strong opponents. Further, we also find differences in the share of neutral associations: while they make only 8% of the total share among strong supporters and opponents, this share rises to 15% for mild opponents. Interestingly, the figure also shows that mild opponents seem to be closer in affective evaluations and type of associations elicited to respondents who are indifferent, than to strong opponents. However, while those who are indifferent seem to recognize the benefit of wind energy in terms of power production, this benefit does not seem to be eminent among mild opponents. In this way, these results highlight that differences appear to not only exist between supporters and opponents, but also within these two groups. This nuance within groups is further highlighted by the nature of the associations. The results show that the more concerned people are, the more they have associations related to landscape, noise, or wildlife.

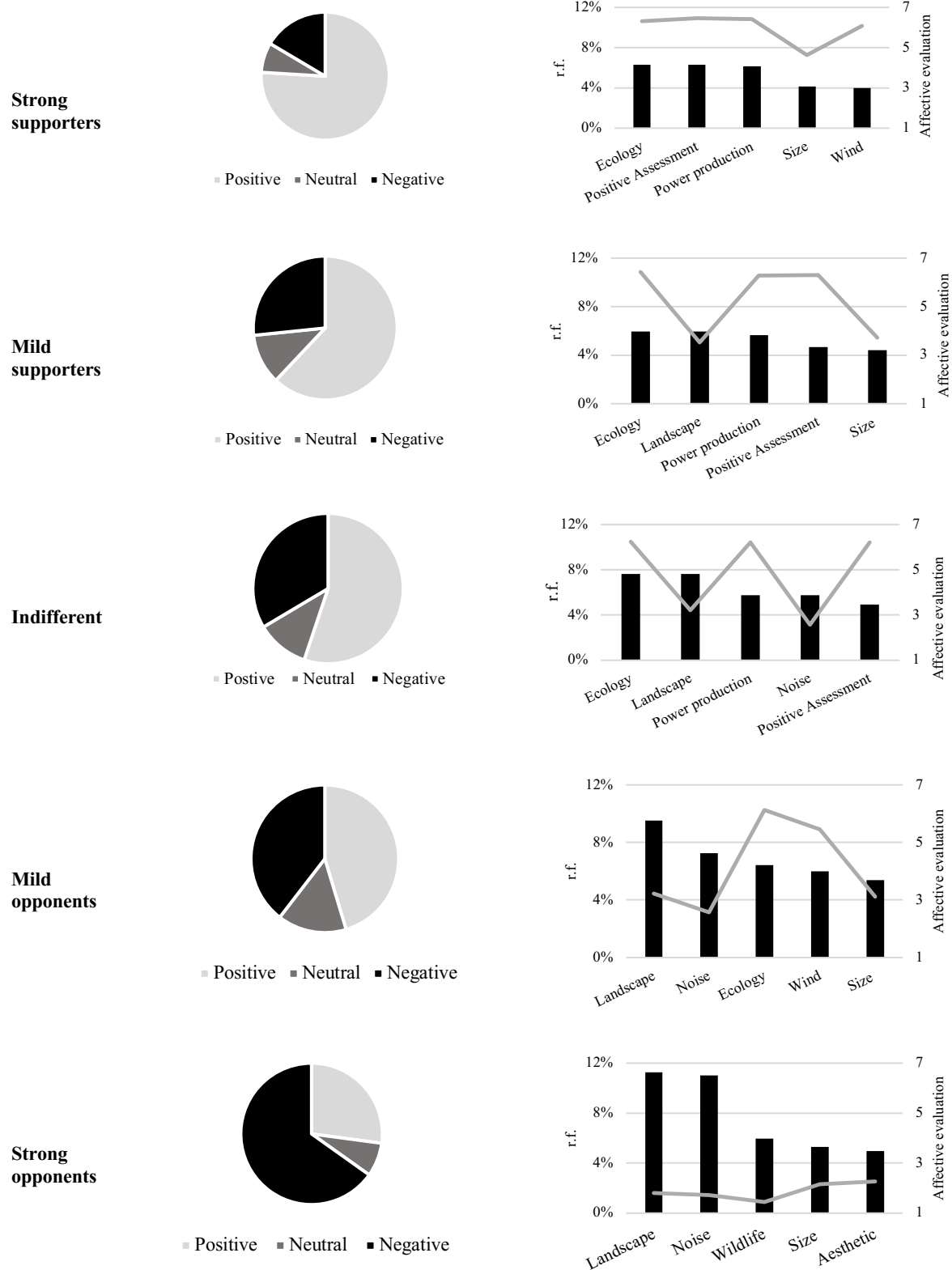


Figure 2: Shares of positive, neutral and negative associations per level of concern and the five main categories of associations elicited

4.3 “Second thoughts” elicited by wind power

An important assumption of query theory is that the order of queries matters. Specifically, the first query usually produces a set of answers that is richer than the subsequent ones and thus, the first query matters most in preference formation (Weber & Johnson, 2011). Applied to our study, we could expect that the first thought or association provided has a bigger weight on local concern for wind power projects than the subsequent thoughts. Importantly, while in query theory, the sequence of thoughts is shown to matter in the context of a specific decision setting, in our study, we did not measure associations about the implementation of a specific wind energy project. Instead, we measured associations elicited by wind energy in general and attitude towards a hypothetical wind energy project. As such, our aim here is to explore whether the first query also matters the most, outside of a specific decision context (e.g. when eliciting thoughts about wind energy in general).¹⁷

So far, we analysed all images and their evaluations provided in one single group, independent of the sequence in which they were given. However, to investigate the potential importance of second thoughts, we now compare how the mean of the affective evaluations varies depending on the sequence in which they were given. Respondents could give a minimum of one and a maximum of five associations when asked to list what came to their mind as they thought of wind power (i.e. five sequences).

4.3.1 General evaluation of first versus subsequent thoughts

The results, depicted in Tables 3 and 4, highlight significant differences in affective evaluations of the first thought versus subsequent ones. Specifically, the first thought is significantly more positive than *second thoughts*.

¹⁷ Past studies using query theory looked at the impact of thoughts directly linked to the decision at hand (e.g., “What comes to your mind as you think about your decision to support or oppose wind projects?”).

Sequence	N	Mean (SD)
1	1111	4.77 (2.107)
2	759	4.29 (2.271)
3	557	4.07 (2.314)
4	294	3.81 (2.202)
5	169	4.13 (2.357)
Total	2890	4.37 (2.241)

Table 3: Mean affective evaluations per sequence

Sequence	Mean Difference	SE	p-values
1 vs. 2	.485*	0.104	<0.001
1 vs. 3	.699*	0.117	<0.001
1 vs. 4	.958*	0.143	<0.001
1 vs. 5	.640*	0.192	0.009

Table 4: Multiple comparisons (Games-Howell) of mean affective evaluations per sequence

4.3.2 First versus subsequent thoughts per level of concern

Further, in the case of strong (=1) and mild supporters (=2), we observe that all associations provided are consistently positive on average (the neutral point is at 4, represented by the horizontal dotted line), but that mild supporters evaluate their first association less positively on average than strong supporters ($N = 464$, $F = 9.058$, $df = 1$, $p = 0.003$, $M_1 = 5.85$, $SD_1 = 1.699$) as well as their second thoughts¹⁸ ($N = 732$, $F = 29.357$, $df = 1$, $p < 0.001$). We find a similar pattern between mild and strong opponents for differences in affective evaluations of first ($N = 462$, $F = 48.953$, $df = 01$, $p < 0.001$ ¹⁹) and second thoughts ($N = 781$, $F = 33.732$, $df = 1$, $p < 0.001$). Interestingly, we do not find significant differences between mild supporters, and respondents who are indifferent, for the evaluations of both the first ($p = 0.153$) and second thoughts ($p = 0.244$). Figure 3 also highlights that only the mild opponent group has both negative and positive thoughts, on average.

¹⁸ The evaluations of all second thoughts (or associations) were aggregated.

¹⁹ Levene's test was significant at $p < 0.001$ but results of a Welch test indicated ($F = 53.153$, $df_1 = 1$, $df_2 = 405.248$, $p < 0.001$).

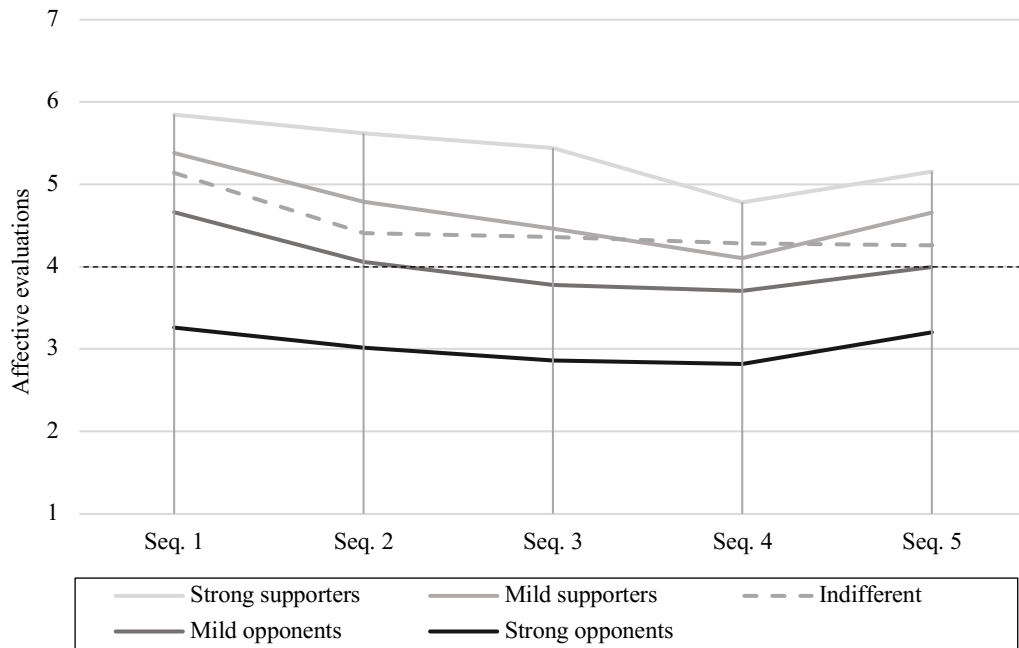


Figure 3: Sequence of affective evaluations per level of concern

Next, applying query theory, one would assume the first thought to be positive for supporters of local wind energy projects, and negative, for opponents. However, we find that this is the case for all groups, except for mild opponents. Specifically, the results highlight that there exists a statistically significant difference ($N = 632$, $F = 169.276$, $df = 1$, $p < 0.001^{20}$) in the sequence in which negative and positive associations are provided based on the level of local concern. Figure 4 further highlights that while for 69% of strong opponents, the first association elicited about wind energy is negative, it is not the case for mild opponents. Indeed, we find that this is the case for only 38% of them. In general, the results show that the first association elicited seems to matter the most for all groups, except for those who are mild opponents. Indeed, while their first thought is positive, mild opponents eventually indicate negative attitudes towards the implementation of local wind energy projects.

²⁰ Levene's test was significant at $p = 0.047$ but results of a Welch test indicated ($F = 174.724$, $df1 = 1$, $df2 = 485.112$, $p < 0.001$).

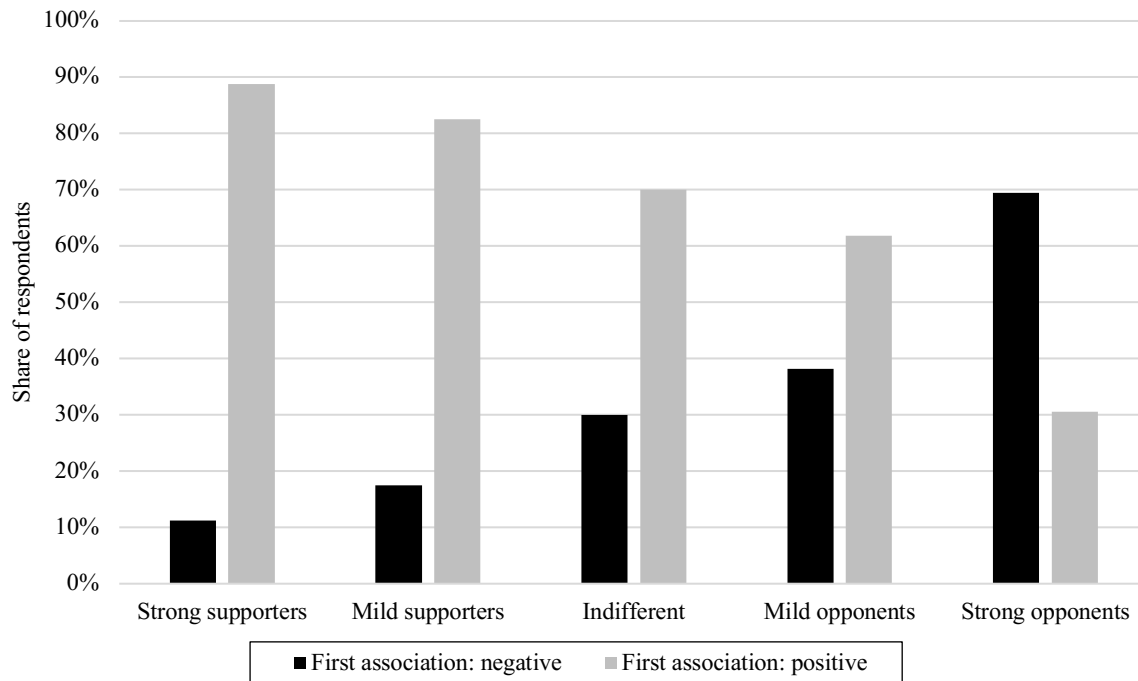


Figure 4: Valence of first association or thought elicited per level of concern

5. Conclusion and policy implications

The main goal of this study was to investigate respondents' affective imagery to wind power, to better understand the processes determining local concern about wind energy projects. Specifically, we went beyond previous studies by (1) analysing the sequencing of the associations provided when respondents thought about wind energy rather than looking only at the most frequent associations elicited; (2) exploring how affective imagery varies based on individuals' characteristics; (3) comparing associations between opponents and supporters by differentiating between strong and mild ones to better understand the perceptions and concerns of the silent majority (King & Anderson, 1971; Leitch & Davenport, 2006). This study is the first to carry out a thorough analysis of people's affective imagery concerning wind power. We used a funnel approach by first analysing affective imagery at a general level, and then focusing on the sequence of positive and negative associations that occurred as people were thinking about wind energy. We could demonstrate that affective imagery plays a crucial role in shaping public perceptions and

therefore influences support or opposition to the implementation of wind power projects. Further, our results show that significant differences exist between strong or mild supporters and opponents, signaling that segmentation of target groups is warranted when trying to manage processes of social acceptance. The results also highlight that the issue of social acceptance of wind energy is more complex than a pro-wind versus anti-wind discourse supporting previous results by Walker et al. (2014) or Rand and Hoen (2017).

5.1 Affective imagery elicited by wind power

Regarding general affective imagery elicited by wind power, this study adds nuances to previous findings which concluded that positive perceptions dominate (Truelove, 2012). Specifically, in contrast to Truelove (2012), who found that wind power generated almost entirely positive associations in a U.S. sample, we find that affective evaluation of wind power among Swiss respondents shows mixed feelings, with 51% of positive associations. Differences between the two samples could be explained by: 1. increased controversy about wind energy in recent years (Walker et al., 2018), 2. Switzerland being more densely populated than the United States²¹, 3. a lack of representativeness in the sample (N = 94) of Truelove (2012). More precisely, in our study, the results highlighted that associations related to landscape, wildlife and noise make up 19% of the total associations elicited. These negative associations seem to be related to expected impacts, rather than actual perceived impacts of wind energy. Indeed, only 37 wind power installations are currently installed in Switzerland, and most people live far away from where they could see or hear those existing facilities. This observation is similar to what Leiserowitz and Smith (2017) found regarding images elicited by climate change: while very few Americans live on the shores of the Arctic Sea, there was a predominance of associations to melting ice when respondents thought about climate change. The authors noted that it was likely due to the prevalence of melting ice images accompanying news stories about climate change. One could think of a similar phenomenon regarding wind power. Further, the results show that,

²¹ 219 P/Km² for Switzerland versus 36 P/Km² for the United States.

Source: <https://www.worldometers.info/world-population/us-population/>.

in general, positive associations elicited by wind power (e.g., ecology, wind) are more abstract than negative ones. It thus appears that individuals have more difficulty grasping concrete benefits from wind energy than potential drawbacks from it. Thus, affective imagery, which is at the root of opposition against wind power, seems to be significantly more elaborated than the factors underlying support for wind power, suggesting that it is harder to change people's attitude from negative to positive than vice versa. This observation may be further supported by the fact that increased energy independence from local production of wind energy has rarely been mentioned by respondents. Moreover, the results showed that only 11% of the associations were rated neutrally, on average, which appears to show that a large part of the population has relatively strong feelings about wind energy.

When investigating differences in associations and related affective evaluations between respondents, we identified a significant generation gap. Not only are younger people more positive about wind energy, but also different types of associations are evoked. For example, associations concerning landscape or wildlife occur twice less among people 30 years of age than those 60 or above. This result suggests that younger generations may be more open to wind power projects, which is in line with studies that have shown that younger people appear to be more open to wind energy than older generations (Cousse & Wüstenhagen, 2019). Also, we found that familiarity matters to explain associations elicited by wind energy. For example, the study highlights that those unfamiliar with the technology think three times more often about wildlife than those familiar with it, suggesting the existence of misconceptions about the impacts of wind energy production. Further, a higher focus on noise among the French-speaking respondents may be explained by the hypothesis about support for wind parks over time (Wolsink, 1994) described in Section 2.1. With several wind park projects currently in the planning phase in the French-speaking part of the country,²² a share of the French-speaking population might find itself in the second phase of the U-shaped curve, namely the phase where public attitudes are most critical. If the hypothesis holds, we could expect the attitudes of this group to rebound as projects are

²² Within our sample, 32.4% of the French-speaking respondents live close to a planned wind energy project versus 10.1% among the German-speaking respondents.

completed. As such, similarly to the work of Leiserowitz (2005) in the context of climate change, this research identifies the existence of distinct “interpretive communities”— each strongly predisposed to interpret wind energy and its potential benefits or nuisances in different ways. Communication strategies should thus be targeted based on specific demographic characteristics.

5.2 Affective imagery elicited by wind power and local concern

Controlling for important variables such as political orientation or place of residence (urban versus rural), we found a strong correlation between the affective evaluations of the associations about wind energy and respondents local concern about wind projects. This suggests that affect matters in the formation of attitudes towards local wind energy projects. Further, the results highlighted that French- speaking respondents, respondents from the national conservative party and individuals unfamiliar with seeing wind turbines in their immediate environment had a significantly higher concern level. These results are in line with results of the previous section highlighting the important role of affective imagery in attitudes. It also opens the way for further research to investigate these variables using structural equation modelling or log-linear analysis.

Segmenting further respondents according to their level of local concern, we were able to produce valuable insights into the affective mental representations latent to attitudes towards local wind energy projects. The results show that mild opponents have more similar associations and related affective evaluations to respondents who are indifferent about the implementation of local wind energy projects than to strong opponents. This highlights that this group of mild opponents may represent a silent part of the population which could change their mind in the process.

5.3 The importance of “second thoughts” for attitudes towards wind power

Another key contribution of our study is to look beyond the primary association or thought elicited. Energy-related decisions are often complex, and consequently, the thought

process of people regarding different energy technologies is complex as well. Our study finds that “second thoughts” are, on average, more negative than the first one, and that within the first five thoughts that come to mind, many respondents go through some sort of a U-shaped curve. This would imply that if project developers want to succeed in gaining social acceptance, they would have to make sure that the local population actually overcomes the negative “second thoughts” and keep considering the issue thoroughly in order to return to their initial level of sympathy for the technology. In times of social media, where attention spans are short, half-truths tend to spread quickly and in-depth reflection may be a scarce resource, this might be a challenge. This finding may also be an explanation for the “acceptance gap” that has been identified in previous literature, in that general surveys tend to be better at capturing first thoughts, while the subsequent stages of the thought process actually matter for the overall evaluation of a project.

Moreover, an in-depth analysis of second thoughts may be particularly important to gain a better understanding of the large part of the population that shows neither strong support nor strong opposition to wind energy. Looking at the second thoughts of mild supporters and mild opponents may provide valuable insights about arguments that can actually tip the balance for them in the process. Figure 2, in Section 4.2.2 may already give us some insights: while power generation is one of the main five associations elicited by mild supporters and indifferent individuals, this is not the case for mild opponents. Therefore, emphasizing the contribution of wind power towards securing domestic electricity supply and contributing to energy independence may be a factor tipping the balance towards support for mild opponents.

Finally, the analysis of first versus second thoughts reveals that the first thought is a robust predictor of preference formation for most but not all groups. In the case of mild opponents, while a large majority of them have a positive first thought about wind energy, their attitude towards local wind energy projects is negative. As such, query theory turns out to provide a useful framework for predicting attitudes of many respondents, but it does not seem to fully apply to one segment of the population which could actually be crucial in tipping the balance in processes of local acceptance.

5.4 Specific policy implications

Countries which are trying to implement a low-carbon energy strategy are facing challenges when it comes to local implementation of infrastructure projects, such as onshore wind. Understanding the affective components of local concern appears key to help with the implementation as the issue has become increasingly emotional in many countries (Cass & Walker, 2009; Perlaviciute et al., 2018). This study contributes to this area by identifying the affective imagery elicited by wind energy and by pointing to the importance of “second thoughts” about the technology to tip the balance towards opposition for individuals who have mixed feelings about the technology. Policymakers and project developers looking for successful implementation of wind power projects should not be blinded by the vocal opinions of strong supporters or strong opponents but pay much more attention to the silent majority of people who are initially undecided. Better understanding their specific concerns, and especially better attending to their “second thoughts”, which tend to be more critical than first thoughts, appears to be crucial in tipping the balance towards support.

Further, while a variety of studies have highlighted that people value energy independence (Fast, 2013; Volken et al., 2018; Stefanello et al., 2019), this is rarely reflected in respondents’ associations with wind power. To increase social acceptance of renewables, policymakers could emphasize the link between generating wind power domestically and reducing import dependence. This may be particularly useful for conservative parts of the population, for whom independence is highly valued (The Local, 2019).

The study further indicates that affect plays a significant role in people's perceptions of wind power. Policymakers should, therefore, take emotions into account – one cannot rely only on addressing the population with facts and figures. Factual information can help to address some of people's concerns, for example, misperceptions. However, being mindful of negative emotions like fear and anger, and strengthening positive emotions like curiosity and pride, is an equally important part of the social acceptance equation.

The results also show that only looking at opinions on a general level, does not reflect the full picture. Instead, researchers and policymakers should make sure that their analysis

is tailored to local processes. Strengthening a sense of local ownership, for example through the role of renewable energy cooperatives or citizen investment (Bauwens, 2016; Walker & Baxter, 2017), may be an important element of social acceptance processes. Increasing people's involvement can make it more likely that they actually re-emerge from the negative second thoughts that may sometimes take precedence in more superficial evaluations of the pros and cons of wind parks.

Finally, our findings show that social acceptance is more than an individual-level phenomenon. We illustrate that different types of supporters and opponents exist depending on different socio-demographic variables such as political orientation or age group. Also, the results highlight that mild opponents are more similar to respondents who are indifferent about the implementation of local wind energy projects than to strong opponents. This can be a first step towards understanding the social dynamics of renewable energy acceptance, in particular polarization. While we acknowledge that each person is unique, similarities in individuals' reactions to wind energy highlight the opportunity to identify specific groups who share similar concerns. This can allow for a certain degree of segmentation, although it is important to keep in mind that in sparsely populated rural areas, a key bottleneck might not be the average perceptions of the wider population, but rather acceptance by a small number of relevant stakeholders in the local community. In sum, while the findings acknowledge the relevance of well-established factors like procedural and distributive justice as key prerequisites for the implementation of wind energy projects, social acceptance can be further supported by carefully targeted communication strategies addressing the salient concerns of the local population.

5.5 Limitations and future research

While our study is based on a large-scale survey and has been carefully crafted to capture respondents' affective imagery related to wind power, we identify three limitations that can be the starting point for further research. First, public perception and acceptance of energy technologies are, to some degree, influenced by a country's geographical and political context. The empirical context of our study is a small and densely populated country with

an emerging wind energy sector. Replications of our study in other geographic settings, including more mature wind markets, could provide important additional insights.

As an exploratory study, a second limitation is the correlational nature of the research findings. The survey data being cross-sectional, we cannot determine the causal relationship between variables, although a large number of past studies have shown that affective reactions guide following judgment (e.g., Zajonc, 1980; Johnson & Tversky, 1983; Peters & Slovic, 1996).

A third limitation results from the operationalization of local acceptance of wind power. We measured local acceptance by asking how concerned participants would be if a wind park were to be built close to their homes or other places, they feel close to. The cross-sectional design of our study – and in fact, of most studies on social acceptance – does not allow us to assess if and how such concern actually translates into active opposition. Future research could try to take a longitudinal approach to measure affect, concern and local acceptance in the context of projects progressing through different planning stages. One challenge to overcome in doing so is to deal with inherently smaller sample sizes in the context of local wind projects.

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Appendix

Appendix A: Overall sample distribution

Variable	Sample before the boost (n=933)	Boost sample (n=178)	Total sample (n=1111)	Swiss adult population
Age				
18-29	22%	10%	20%	18%
30-44	25%	26%	25%	26%
45-59	27%	29%	27%	28%
60+	26%	34%	27%	28%
Gender				
♂	50%	58%	51%	49%
♀	50%	42%	49%	51%
Region (excl. Ticino)				
Western Switzerland (French-speaking)	25%	56%	30%	25%
Alps & Prealps	25%	27%	25%	24%
Swiss Plateau West	22%	7%	20%	22%
Swiss Plateau East	28%	10%	25%	29%
Education				
low/medium	62%	46%	59%	62%
high	38%	54%	41%	38%
Partisan Orientation				
Swiss People's Party (SVP)	29%	14%	26%	29%
The Liberals (FDP)	16%	19%	16%	16%
Conservative Democratic Party (BDP)	5%	2%	4%	4%
Green Liberal Party (GLP)	5%	12%	6%	5%
Christian Democratic People's Party (CVP)	12%	12%	12%	12%
Green Party (GPS)	7%	10%	8%	7%
Social Democratic Party (SP)	20%	23%	21%	19%
Others	7%	8%	7%	8%

Notes: Information on socio-demographic characteristics of the Swiss voting population was obtained from the Swiss Federal Statistical Office. The political orientation's distribution corresponds to the results of the 2015 parliamentary election to the lower chamber of the national parliament (National Council): <https://www.bfs.admin.ch/bfs/fr/home/statistiques/politique/elections/conseil-national/force-partis.html>

Appendix B: Survey questions

Variables	Questions	Answer options
Affective imagery	“What are the first thoughts or images that come to your mind when you think of wind energy ?”	1 to 5 association(s) listed
Affective evaluations	What are your feelings regarding the thought or images you provided about wind energy? <i>Please use the scale below to evaluate your feeling from very negative to very positive. Each thought or image needs to be evaluated separately.</i>	1 (very negative) to 7 (very positive)
Familiarity with wind energy	<i>Please indicate the extent to which you agree with the following statement:</i> “I am familiar with seeing wind turbines in my immediate environment”.	1 (fully disagree) to 4 (fully agree) 5 (I do not know)
Local concern	<i>Please indicate the extent to which you agree with the following statement:</i> “I would be concerned if a wind turbine would be built in my neighbourhood or other places, I feel close to”.	1 (totally disagree) to 5 (totally agree) 6 (I do not know/no opinion)
Awareness about planned wind project	“Is the implementation of wind turbines planned near your home (less than 5 km away)?”	1 (yes), 2 (No), 3 (I do not know)

Appendix B: Survey questions

Appendix C: Descriptive statistics of variables used in the analyses

N=1'111	Mean	SD	Min.	Max.
Affective evaluations	4.526	1.832	1 (very negative)	7 (very positive)
Familiarity with wind energy	1.82	1.012	1 (very unfamiliar)	4 (very familiar)
Local concern	3.06	1.489	1 (not concerned at all)	5 (highly concerned)
Awareness about planned wind project	.10	0.305	0 (not aware)	1 (aware)
Place of residence	2.97	1.152	1 (city center)	4 (rural area)
<i>Socio-demographic variables</i>				
Age	2.61	1.091	1 (below 30)	4 (60 and above)
Gender	1.49	0.500	1 (male)	2 (female)
Education	0.41	0.492	0 (compulsory education)	1 (University / higher education)
Language Region	0.3	0.460	0 (German)	1 (French)
Political Orientation	0.74	0.440	0 (Swiss national conservative party)	1 (other political parties)

Appendix C: Descriptive statistics of variables used in the analyses

Appendix D: Sample split of German- and French-speaking respondents based on proximity to existing and planned wind park

Proximity to wind park	German-speaking subsample (% / n)		French-speaking subsample (% / n)		Entire sample (% / n)	
Live in proximity to an existing wind park	5.0%	39	14.3%	48	7.8%	87
Live in proximity to a planned wind park	10.1%	78	32.4%	109	16.8%	187
Do neither live in proximity to an existing nor to a planned wind park.	84.9%	658	53.3%	179	75.3%	837
<i>Total</i>	100.0%	775	100.0%	336	100.0%	1111

Appendix D: Sample split of German- and French-speaking respondents based on proximity to existing and planned wind park

Appendix E: Sample split of German- and French-speaking respondents based on residential location

Residential location	German-speaking subsample (% / n)		French-speaking subsample (% / n)		Entire sample (% / n)	
City centre	17.8%	138	20.0%	68	18.5%	206
Suburban	13.7%	106	8.8%	30	12.2%	136
Agglomeration	24.0%	186	20.3%	69	23.0%	255
Rural	44.5%	345	49.7%	169	46.3%	514
Total	100.0%	775	100.0%	340	100.0%	1111

Appendix E: Sample split of German- and French-speaking respondents based on residential location

Appendix F: Sample split per age group and residential location

Residential location	Below 30 (% / n)		30-44 (% / n)		45-59 (% / n)		Above 60 (% / n)	
City centre	13.7%	31	21.3%	60	17.9%	54	20.3%	61
Suburban	15.4%	35	9.9%	28	8.0%	24	16.3%	49
Agglomeration	25.1%	57	19.5%	55	23.6%	71	23.9%	72
Rural	45.8%	104	49.3%	139	50.5%	152	39.5%	119
Total	100.0%	775	100.0%	282	100.0%	301	100.0%	301

Appendix F: Sample split per age group and residential location

Appendix G: Definition of the categories

Category name	The thought or short sentence contains...:
Wind turbine	...wind turbine, windmill (e.g. wind turbine; ugly wind turbine) In the second case, the thought was also categorized in the Aesthetic category.
Mill	... mill
Wind park	... wind park or wind farm.
Wind	... the word wind or synonyms of wind such as "North Wind" (Bise) only.
Air	... air
Environment & Ecology	... elements related to the environment and the ecology (e.g. Environmentally friendly, ecological)
Nature	... elements related directly to nature (e.g. nature protection)
Climate	... climate change
Sustainability	... sustainability sustainable.
Deficit	... elements related to a deficit of wind energy production (e.g. "Should be used more")
Technology	... elements related directly to the technology.
Positive Assessment	... elements that assess wind energy positively but are unspecific (e.g. interesting)

Appendix G: Definition of the categories

Category name	The thought or short sentence contains...:
Negative assessment	... elements that assess wind energy negatively but are not specific (e.g. unpractical)
Size	... elements related to the size of wind turbines (e.g. big, huge)
Space scarcity	... elements related to the space wind turbines take (e.g. "lack of space"; "needs a lot of space")
Noise	... elements related to the noise wind turbines may emit
Profitability/costs/economy	... elements related to the (un)profitability, costs of wind turbines (e.g. "maintenance is too expensive"; "cost savings"; "cheap")
Efficiency	... elements related to efficiency (e.g. "simply produces a lot of electricity"; "large expenditure for little energy")
Intermittency/reliability/storage	... elements related to the intermittency of wind energy production (e.g. "fluctuating power generation")
Landscape	... elements related to the landscape (e.g. "landscape"; "destroys the landscape")
Wildlife/Fauna	... elements related to fauna as a whole (e.g. "Deadly for birds, bats and insects")
Aesthetic	... elements related to the aesthetic of wind turbines (e.g. "ugly"; "beautiful")
Shade	... elements related to the shade wind turbines may cause
Geographic suitability	... elements related suitability of wind energy installations (e.g. "at the right place"; "Question of location")
Place reminiscence	... thoughts or statements mentioning specific locations (e.g. "Mont Crosin"; "Germany")

Appendix G: Definition of the categories (cont.)

Category name	The thought or short sentence contains....:
Suitability in Switzerland	... thoughts or statements mentioning suitability of wind energy production in Switzerland
Independence	... thoughts or statements mentioning energy independence
Danger	... elements linked to danger
Acceptance challenges	... elements mentioning acceptance challenges linked to wind turbines (e.g. "false anxieties"; "many objections")
Implementation	... elements linked to the implementation of wind energy projects (e.g. "transport" or "strategies")
Colour	... mention of colours (e.g. "white")
Coldness	... elements linked to coldness (e.g. "coldness")
NIMBY	... elements related to not wanting a wind turbine close by (e.g. "I'd rather it to be in my neighbour's house than mine!")
Power production	... elements related to energy, electricity or power production (e.g. "power"; "energy").
Unlimited source	... elements linked to the availability of the wind to produce energy (e.g. "Infinite Energy")
Renewable energy	... renewable energy.
Free energy	... elements mentioning that wind energy is "free".
Clean energy	... elements related to the idea that wind energy is clean (e.g. "clean energy"). To be differentiated from "green energy" categorized in Environment & Ecology.

Appendix G: Definition of the categories (cont.)

Category name	The thought or short sentence contains....:
Alternative energy	... elements related to ideas that wind energy is an alternative energy.
Field	... elements related to "fields" (e.g. "grazing areas")
Storm	... elements related to "storms" (e.g. "storm damages")
Mountains	... elements related to the mountains or thoughts picturing wind turbines in the mountains (e.g. "mountain"; "wind turbines in the mountains"). In the second case, the thought was also categorized in the Wind turbine category.
Ocean	... elements related to the ocean or thoughts picturing wind turbines in the ocean (e.g. "ocean"; "wind turbines in the sea"). In the second case, the thought was also categorized in the Wind turbine category.
Tower	... elements related to the tower of wind turbines (e.g. "tower", "high towers"). For instance, in the case of "high towers", it was categorized two times: 1. in Tower; 2. in Size.
Propeller	... elements related to the rotors of wind turbines (e.g. "propeller", "huge propeller"). In the case of "huge propeller" for example, it was categorized two times: 1. in Propeller; 2. in Size.
Subsidies	... elements related to subsidies given to wind power projects
Future	... elements related to the future (e.g. "future"; "Kinderschuhe")
Knowledge gaps	... elements linked to lack of knowledge (e.g. "not informed enough")
Energy Mix	... any elements linked to other energy sources or the role of wind energy in the energy mix.
Other	... any elements that could not be categorized in the above categories

Appendix G: Definition of the categories (cont.)

Paper II

Still in love with solar energy?¹ Installation size, affect, and the social acceptance of renewable energy technologies

*Julia Cousse*²³

Abstract

Solar and wind energy are expected to play a key role in creating a climate-neutral Europe by 2050 and decarbonizing energy production in general, albeit requiring significant deployment. This presupposes that the population accepts such energy sources, thus necessitates understanding how people perceive energy systems. Unlike the abundant literature about wind energy, social acceptance of solar energy has received less attention, especially concerning large solar installations. Opinion polls indicate that solar energy enjoys a high level of socio-political acceptance and is preferred to other renewables, although it is unclear whether this acceptance persists as the technology is deployed on a large scale. This paper helps close this gap by describing the results of a representative survey (n=601) conducted using a between-subject design to examine how attitudes of the public towards solar energy vary based on the size of installations, how the latter compare to attitudes towards wind energy, and what the role of feelings is in the former. Results reveal that the stronger preference for solar power decreases to a similar level as that for wind energy when comparing installation of similar sizes, highlighting that solar energy installations may not easily be scaled up. The study also shows that affect plays an important role in forming people's attitudes towards wind and solar, especially concerning large-scale installations. This underlines the need for policymakers and project developers, who aim to deploy renewables on a large scale, to attend to the affective component of decision-making.

Keywords: Photovoltaics, Solar energy, Social acceptance, Affect, Emotions

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1. Introduction

Recent research suggests that investment into climate-friendly policy initiatives may help the world move closer to a net-zero emissions pathway, as targeted in the 2020 European Green Deal (European Commission, 2019), and could also offer the best economic returns on government spending (O’Callaghan & Hepburn, 2020). Among the policies that are both most effective and sustainable are those that promote investment into greener infrastructure, in particular renewable energies, energy storage, and the modernization of the electricity grid (O’Callaghan & Hepburn, 2020). Of all the renewables, solar energy is one of the fastest growing energy sources and could therefore contribute substantially to reducing dependence on fossil fuels and decreasing global CO₂ emissions (Carlisle et al., 2014). However, apart from technical challenges, the social acceptance of renewables appears central to the latter. At first glance, the issue of the acceptance of renewables might seem unproblematic, as several studies have revealed a high level of general⁴ acceptance of renewables (e.g., Gamma et al., 2017; Volken et al., 2017). However, concerning the actual implementation of projects, policymakers face considerable local resistance (e.g., Walker & Baxter, 2017), which may increase exponentially as renewables are deployed on a larger scale. This is particularly problematic for a country such as Switzerland, which is lagging in terms of production of solar and wind energy and needs to increase its share of renewables significantly to meet the objective of reducing CO₂ emissions to zero by 2050 (Iten & Nipkow, 2019).

While many studies have focused on the social acceptance of wind energy in recent years (Rand & Hoen, 2017; Jami & Walsh, 2017; Firestone et al., 2018; Dwyer & Bidwell, 2019), the social acceptance of solar energy, and more specifically of utility-scale solar photovoltaics, has received less attention (Michel et al., 2015; Brewer et al., 2015; Carlisle et al., 2015; Wissen et al., 2019). However, while solar energy enjoys a high level of general acceptance of the population and appears to be greatly preferred to other renewable energy sources (Gamma et al., 2017; Sütterlin & Siegrist, 2017; Cranmer et al., 2020), it is yet unclear whether the preference for this technology persists if the technology is deployed on

⁴ *General* acceptance of renewables is also referred to *socio-political* acceptance (Wüstenhagen et al., 2007).

a larger scale. Accordingly, obtaining valid data about people's preferences for energy technologies, along with the factors that shape those preferences, can help policymakers overcome social-acceptance-related issues associated with the implementation of renewable energy projects (Enevoldsen, 2016; Enevoldsen & Sovacool, 2016).

Further, within the literature on the social acceptance of renewables, Devine-Wright (2009) highlights that the implementation of energy projects can disturb emotional bonds to places. One might thus expect that such emotional bonds would be more strongly disrupted as the size of a technological installation increases. However, emotional reactions to the siting of solar energy projects are still underexplored, although they appear to be a key element in the creation of the attitudes of the population towards energy projects. An increasing body of literature has shown that affect – the specific quality of something being good or bad, experienced as a feeling (Leiserowitz, 2006) - plays an important role in decision-making (Johnson & Tversky, 1983; Epstein, 1994; Peters & Slovic, 1996), including in the context of preferences for energy sources (Huijts et al., 2012; Truelove, 2012).

Based on these considerations, it appears important to investigate whether the high acceptance level enjoyed by solar energy is likely to persist if the technology is deployed on a large scale⁵, or whether it may face resistance similar to that associated with wind energy projects. For this purpose, the current study investigates how specific attitudes⁶ towards solar energy vary based on the size of the installation (solar rooftop versus utility-scale solar⁷) and compare these to specific attitudes towards wind energy installations. Further, given the importance of affect in attitude formation, it explores how feelings elicited by solar and wind energy influence the relationship between energy technologies and attitudes. The specific research questions are presented below:

⁵ Note: *Scale*, in the current study refers to the size of the energy infrastructure only (e.g., Sustainable Energy Ireland, 2003; Wolsink, 1989) as opposed to local and national levels, for example (e.g., Devine-Wright, 2007)

⁶ "Specific attitude" refers to attitudes towards local energy projects, "e.g., what people think about wind energy projects in their vicinity, regardless of the specific project characteristics" (Walter, 2014, p.79)

⁷ In this study, "solar rooftop versus utility-scale solar" does not imply a difference in ownership structure but in installation size only.

1. *How do differences in attitudes towards solar energy vary based on the size of installations, and how do the latter compare to attitudes towards wind energy installations?*
2. *What is the role of feelings in the development of attitudes towards the different energy installations?*

In brief, the study finds that (1) attitudes towards solar and wind park installations of a comparable size do not differ; (2) feelings have a mediating role in the formation of attitudes; and, (3) the feelings elicited by energy installations have the largest effect on attitudes in the case of large-scale energy installations. The rest of the paper is organized as follows: Section 2 discusses and reviews relevant literature in the field of the social acceptance of renewable energies; Section 3 describes data and methods; and Section 4 presents the empirical findings. Finally, Section 5 discusses the most important findings in light of the literature, and includes a conclusion, policy implications, limitations, and suggestions for further research.

2. Literature review

2.1 Social acceptance of renewables

An increasing amount of research has investigated the social acceptance of renewable energy in recent years (e.g. Wüstenhagen et al., 2007; Batel et al., 2013). Wüstenhagen et al. (2007) list three different levels of social acceptance: socio-political, community and market acceptance. These three levels are not only interrelated but also involve different actors (project developers, policymakers, consumers) who are involved in different levels (Wolsink, 2018a). For example, an increase in challenges in the area of community acceptance (i.e., local acceptance) can impact pre-existing high levels of socio-political acceptance (i.e., general acceptance). This implies that social acceptance is a multidimensional and dynamic phenomenon (Upham et al., 2015; Ellis & Ferraro, 2016).

Several studies have found high socio-political acceptance of the different types thereof (Walter, 2014; Cousse & Wüstenhagen, 2018). In terms of the acceptance of different

renewable energy technologies, solar energy stands out due to its positive socio-political perception and acceptance (Sütterlin & Siegrist, 2017; Cousse & Wüstenhagen, 2018; Jobin & Siegrist, 2018). However, high levels of socio-political acceptance are a necessary but not sufficient condition for the successful deployment of energy technologies. Regarding wind energy, different studies have identified high levels of socio-political acceptance (Ellis & Ferraro, 2016; Langer et al., 2018), but wind energy projects frequently face acceptance-related issues on a local level that impede their deployment (Horbaty et al., 2012). Moreover, solar and wind energy have experienced impressive learning curves resulting in significant cost reductions (IRENA, 2016; IRENA, 2019) making renewables the most cost-effective source of new electricity generation (IRENA, 2019). This has led researchers to argue that the socio-political and market dimensions of the socio-political triangle (Wüstenhagen et al., 2007) are not the main limiting factors in the implementation of renewable energy projects (Ellis & Ferraro, 2016), but that community acceptance is (Firestone et al., 2018; Dwyer & Bidwell, 2019). As such, an important question is to what extent high levels of socio-political acceptance translate into high levels of local acceptance of the installation of energy projects themselves when one moves from an abstract ideas about an energy source towards more concrete ones (Sütterlin & Siegrist, 2017).

For many individuals, the transition to renewables is experienced as the extension of the energy system into places that were formerly untouched (Bridge et al., 2013, p. 335). Such interference with previously “unaffected” land appears to play an important role in the acceptance of energy sources at the local level. Wolsink (2000) has, for example, highlighted the fact that the visual impact of wind turbines on the landscape plays a significant role in the overall acceptance of wind power. Research has also noted that decision-making about the spatial implications of the implementations of renewable energy projects mainly involves landscape issues, not only in terms of physical options for siting, but also the assessment of landscape values that may be affected by the infrastructure (Wolsink, 2018b). Regarding the latter, the concepts of ‘visibility’ and ‘visual impact’ must be distinguished (Wolsink, 2018b) as the implementation of energy projects must be planned not only in terms of their visibility, but also in terms of their visual impact: namely, the change in the quality of the landscape induced by the siting of the energy infrastructure (Wolsink, 2018b). Changes in the quality of the landscape are subjective as they are mainly

due to individuals' different assessments thereof. Accordingly, the relationship between visual impact, landscape and perception by the population is complex (Wolsink, 2018b) and the implementation of projects that do not take into account how the visual impact of energy projects may disrupt people's values and emotions may hit roadblocks (Devine-Wright, 2009; Wolsink, 2018b). However, little research exists about the perception of the population concerning the visual impact of solar energy installations (e.g., Sanchez-Pantoja et al., 2018) and, more importantly, how such perceptions may vary based on the size of the installation. Controlling for the size of the installation in the case of solar energy appears to be particularly relevant, as previous research that used a Swiss sample, revealed that people associate solar power specifically with the placement of solar panels on rooftops, and not large-scale installations (Sütterlin & Siegrist, 2017). It is thus yet unclear whether the positive symbolic value attached to solar energy and in turn, high acceptance levels, may be sustained for large-scale solar power plants (Sütterlin & Siegrist, 2017).

While some research has measured socio-political and community acceptance of solar energy (Cousse & Wüstenhagen, 2018), most has focused on wind energy, with the exception of a few cases. Vuichard et al. (2021), using a Swiss sample, found that a majority of respondents would be in favor of solar parks in an alpine region, and that local ownership increases the level of acceptance. Wissen et al. (2019), also using a Swiss sample, showed that deployments of rooftop PV installations are preferred to wind energy and open-space PV installations. Moreover, Carlisle et al. (2015) found, using a US sample, that the public broadly supports the deployment of large-scale solar projects, and this support is not different between deployment considered in general or when located in one's own county. While these studies offer useful insights, it is still unclear if the preference for solar energy over wind energy would be sustained if deployments of a similar size were compared, especially in a smaller country such as Switzerland.

Previous research into the social acceptance of wind energy provides important information on which to base an analysis of attitudes towards solar energy, and specifically, about how attitudes may change based on the size of installations. Factors related to the proposed size of a project have been shown to be significantly related to their support, with larger energy projects being less likely to be favorably received (Smith & Marquez, 2000; Wolsink, 2000; Ladenburg, 2008). Further, Devine-Wright and Batel (2017) highlighted

the need to reconsider the “localist” perspective adopted by earlier research. Specifically, the authors noted that the literature on the social acceptance of renewables can be criticized for taking on a narrow spatial focus. They argued that low carbon energy infrastructure does not only involve local projects. Instead, while having an evident local impact, it also involves concerns on multiple levels (Bridge et al., 2013; Batel & Devine-Wright, 2015; Devine-Wright & Batel, 2017). For example, people may feel loosely attached or estranged from the place in which they presently live (Manzo, 2005; Lewicka, 2011; Devine-Wright & Batel, 2017). In contrast, people may feel a strong attachment to localities other than those in which they now live, such as places where they have previously lived (Smith & Marquez, 2000; Gustafson, 2014; Lewicka, 2014). To contribute to this relatively new way of assessing attitudes towards local energy projects, the current study takes into account these aspects in how it measures the related attitudes by not only assessing attitudes about “local projects” involving energy projects close to respondents’ homes, but also in other places that individuals may feel close to.

2.2 Affect and the social acceptance of energy sources

People's judgments and decisions are oftentimes based on their feelings about objects (e.g., wind turbines) (Slovic et al., 2004). Feelings, which are part of the affective system of decision-making, are based on associative and intuitive processes that generally faster than cognitive processing (Weber & Johnson, 2009). The affect elicited by an object can serve as a quick and efficient signal that contributes to decision-making (Slovic et al., 2007) given that positive or negative feelings associated with objects consequently guide their evaluation (Finucane et al., 2000). However, energy-related preferences have mainly been investigated from a cognitive perspective (e.g., Finucane et al., 2000, Greenberg, 2009; Tabi & Wüstenhagen, 2017; Vuichard et al., 2019), and only a few studies have examined affective factors (Truelove, 2012; Sütterlin & Siegrist, 2017; Jobin et al., 2019; Cousse et al., 2020).

Researchers in the field of psychology have used word-association techniques for a long time (Galton, 1879; Hollway & Jefferson, 2008; Connor & Siegrist, 2011; Joffe & Elsey, 2014). Affective imagery, which is employed in the current research to measure affective

reactions to solar and wind energy, uses word association to reveal the positive and negative associations elicited by a stimulus (Leiserowitz, 2006). Researchers have used affective imagery to investigate different domains, including GM food (Connor & Siegrist, 2011), nuclear power (Peters & Slovic, 1996), and smoking addiction (Benthin et al., 1995).

Specific to energy sources, Jobin and Siegrist (Jobin & Siegrist, 2018) highlighted that affect guided preferences for energy portfolios, and that solar energy generally elicited more positive affect than wind energy. Further, Truelove (2012) found that affect was significant in predicting attitudes towards energy project implementation. Based on the former, the hypothesis is that feelings may have a mediating effect on the relationship between an energy installation and attitudes towards it. To the best of the author's knowledge, although previous findings have highlighted that affect is important in the formation of attitudes towards energy source infrastructures, no studies have yet investigated how affective reactions to solar energy can vary based on the size of installations, or how the affect elicited by solar energy infrastructures of different sizes compares to the affect elicited by wind energy infrastructure.

3. Data and Methods

3.1 Sample

Data were collected through a representative survey of 601 Swiss respondents between March and April 2019. The respondents of the study were selected through a Swiss online panel (n=100,000).⁸ The heart of the questionnaire was a between-subject experiment about the feelings and attitudes evoked by solar and wind energy installations. Data about further variables were also collected: general affective reactions to solar and wind energy, gender, age, language region, political orientation, place of residence, education level, and income. Details about each of the variables can be found in Appendix A. The completion rate was 81.65%.⁹ The sample was representative of the Swiss population with regards to gender,

⁸ The panel was managed by Intervista's. Their panel approach helps create a sample almost equivalent to a probability sample of the Swiss voting population (<https://www.intervista.ch/?lang=en>) as opposed to opt-in panels.

⁹ This figure describes the proportion of completely finished interviews in relation to the number of individuals who clicked on the link to the survey.

age, language region, and political orientation (see Table 1). In addition, 19.0% of respondents indicated living in a city center, 12.6% in the suburbs, 20.1% in an agglomeration, and 47.4% in rural areas, controlling for a potential urban versus rural divide. The Italian and Rhaeto-Romanic speaking regions of Switzerland were not included in the sample, as they constitute only 8% and 0.5% of the Swiss population.

	Total sample n = 601	Swiss population
Age		
15-29	18.50%	23%
30-39	14.50%	18%
40-49	20.00%	19%
50-59	18.80%	20%
60-74	28.30%	20%
Gender		
♂	50.10%	49%
♀	49.90%	51%
Education		
low/medium	63.10%	62%
high	36.90%	38%
Political Orientation		
Conservative (SVP, FDP, CVP)	57.40%	57%
Center-progressive (BDP, GLP)	8.00%	9%
Left-wing (SP, GPS)	26.50%	26%
Other/none	8.20%	8%
Language region		
French-speaking	34.10%	27%
German-speaking	65.90%	73%

Data sources: Gender (BFS, 2018a), Age (BFS, 2018a), Political orientation (BFS, 2018a), and Language region (BFS, 2018b).

Table 1: Structure of the Sample

3.2 Survey design

All participants (n=601) were first surveyed to reveal their general spontaneous associations and related feelings elicited by the stimulus wind and solar energy using the method of continued word association (Slovic et al., 1991; Peters & Slovic, 1996). In a second step, an experimental between-subject design was implemented, and participants were presented with pictures of a solar park, wind park, or rooftop installation within the same landscape (Appendix B). In the experimental between-subject design, each participant was randomly assigned to one treatment group and presented with pictures of a solar park (Group 1, n=197), rooftop solar (Group 2, n=203), or wind park (Group 3, n=201). The use of pictures was deemed to be particularly relevant in the context of this study to ensure that participants mentally visualized similar installations. Additionally, the use of pictures in surveys has shown to be very helpful for understanding people's perceptions (Junker & Buchecker, 2008; Soliva et al., 2008; Fyhri et al., 2009; Michel et al., 2015). The method of continued word associations was also used to measure affective reactions to the pictures. In total, respondents were exposed to two pictures in two very different settings (referred to as Scenario 1: Alpine, and Scenario 2: Midlands) to control for the effect of the surrounding landscape and test whether differences observed between solar and wind energy installations were sustained in different settings. This is important, as past studies have highlighted that perceptions of renewable energy infrastructures such as wind turbines or photovoltaic systems not only depend on the infrastructure itself, but also on the visual impact of the energy infrastructures. The latter involves not only an assessment of the infrastructure as such, but of landscape quality change induced by the siting of the latter (Wolsink, 2007; Michel et al., 2015; Wolsink, 2018b). The pictures were selected to represent environments, which were not sterile but instead could elicit emotional reactions from respondents (i.e., real Swiss landscapes). Further, the two pictures were presented in a random order to control for contamination effects. Note that the design of the energy infrastructure presented in the pictures does not account for regulations relating to whether an energy project could legally be implemented in the given setting, although regulatory issues play an important role in the selection of site development. At the end of the survey, each group was surveyed about their attitude towards the implementation of a hypothetical

solar park, solar rooftop, or wind park installation. Sociodemographic data about each subgroup can be found in Appendix C.

3.3 Measures

3.3.1 Affective reactions

Affective reactions were measured following the method of continued word association, as described by Peters and Slovic (Peters & Slovic, 1996). To measure the general spontaneous associations and related affective evaluations elicited by wind and solar energy, respondents were asked “What are the first thoughts or images that come to your mind when thinking of solar/wind energy?”¹⁰. In a second step, each subgroup was asked: “What are the first thoughts or images that come to your mind when looking at this picture?” (installation-specific level). Respondents were asked to give a minimum of one association, and a maximum of five. Each association provided by the respondents was subsequently evaluated by them on a seven-point affect scale from 1 (“very negative”) to 7 (“very positive”). If a respondent offered five responses, the affective evaluations of each of these was averaged to develop the mean affective evaluation. In the analysis, the mean affective evaluation of the associations was used, which corresponded to the average of every affective evaluation of each respondent.

3.3.2 Local concern

To measure attitudes towards the implementation of the energy infrastructure, a proxy, local concern, which is an attitudinal measure, was used. Further, attitudes to the implementation of the energy infrastructure close to respondents’ homes or other places they may feel close to, rather than attitudes towards the specific projects depicted in the pictures were measured. Specifically, local concern was measured by asking respondents to specify their level of agreement with the following statement: “I would be concerned if a wind park / solar park / solar rooftop installation was built close to my neighborhood or

¹⁰ This question was asked in the exact same form in Cousse et al. (2020)

in other places I feel close to,” on a scale from 1 (“totally disagree”) to 5 (“totally agree”). The design of this question – and in particular, the addition of the phrase “(...) in other places I feel close to” – was motivated by recent research by Devine-Wright and Batel (2017), which highlighted the need to reconsider the “localist” perspective adopted by previous research. An option to select “I do not know” was also available. Respondents were excluded from the analysis if they selected this option ($n=59$).

4. Results

4.1 Attitudes towards solar park-, rooftop solar-, and wind park installations

Figure 1 shows respondents’ average level of local concern about the wind park ($M=3.16$, $SE=0.11$, $N=201$), solar park ($M=2.89$, $SE=0.11$, $N=197$), and rooftop solar installations ($M=1.67$, $SE=0.08$, $N=203$). As noted in the methodological section of the paper, local concern measured attitudes towards hypothetical projects close to respondent’ homes or other places they may feel close to, not attitudes towards the projects in the pictures. Based on a one-way Welch ANOVA¹¹ and Games-Howell post-hoc tests ($F=76.49$, $df_1=2$, $df_2=389.87$), the results indicate that the level of concern about the solar park and the wind park installation ($p=0.16$) was not significantly different. In contrast, the level of concern about solar rooftop installations was found to be significantly different from that expressed in relation to the solar park ($p<0.001$) and wind park installations ($p<0.001$).

¹¹ A Levene’s test was significant at $p<0.001$. A Welch’s ANOVA test was conducted ($F=76.486$, $df_1=2$, $df_2=389.871$, $p<0.001$) and was significant.

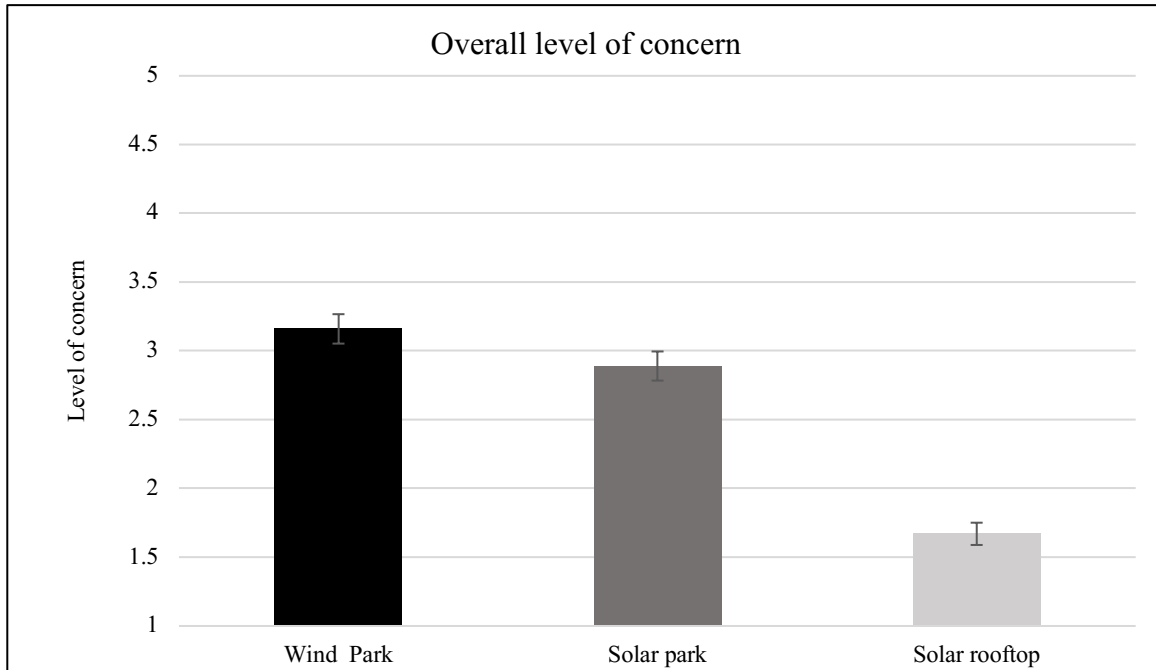


Figure 1: Overall level of local concern for the three different groups of respondents.

4.2 Affective reactions elicited by wind and solar energy

To investigate how feelings varied in relation to the solar and wind energy installations, an investigation of the feelings or affect elicited by wind and solar energy in general, meaning the feelings elicited by the terms “solar energy” and “wind energy” was undertaken, and the distributions of the feelings evoked by solar and wind energy using box plots for the overall sample were evaluated ($n = 601$) (Fig.2).

The distributions of the feelings elicited were not uniform for both solar and wind energy. Over 80% of respondents (83.72%) showed positive affect towards solar energy in general (Median = 6, IQR = 2), whereas only slightly fewer than 60% (57.81%) of respondents demonstrated positive affect towards wind energy in general (Median = 4.75, IQR = 3). The two boxplots further highlight that there exists more variability in affect in the case of wind ($SD = 1.83$) than in the case of solar ($SD = 1.45$). Conducting a one-way Welch ANOVA, it was found that the difference in affect between solar and wind, measured at a general level, was significant ($N=1204$, $F=469.52$, $df=1$, $p<0.001$), being more positive in the case of solar power (Mean=5.74) than in the case of wind power (Mean=4.49). These

results suggest that when individuals think about the two energy sources on an abstract level, solar energy elicits more positive feelings than wind energy.

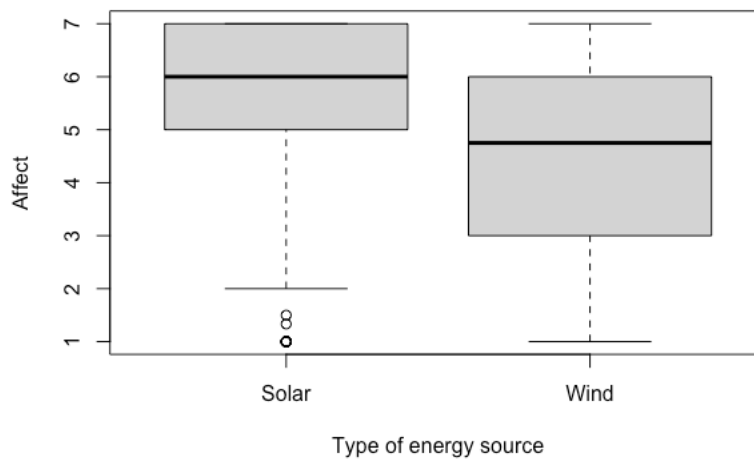


Figure 2: Boxplots of affect elicited by wind and solar energy at a general level, displaying the median, 25th and 75th percentiles

4.3 Affective reactions elicited by wind and solar energy installations

Next, the affect elicited by the solar and wind energy installations, including differences between solar rooftop and solar park installations was investigated. The results were more nuanced than those found at a more general level. Fig.3 shows the affect elicited by solar and wind installations in Scenario 1 (Alpine). Affect here is not only elicited by the energy installations, but also by other elements in the pictures. As such, spontaneous associations and the related affect cannot be solely attributed to the energy installation, but also to other stimuli present in the pictures. Nonetheless, the comparison of energy installations in the exact same landscape controls for noise (i.e. other elements in the picture) and permits the investigation of differences in affective reactions in relation to the installations themselves.

The greatest standard deviation was found in the case of the affect elicited by wind parks ($N = 201$; $SD = 2.18$), followed by solar parks ($N = 197$; $SD = 2.06$), and then solar rooftops ($N = 203$; $SD = 1.04$). The solar rooftop installations ($Mdn=7$, $IQR=1$) elicited positive affect among 96.06% of the sample, while affect appears to be less homogeneous in the case of the wind park or solar park installations. For example, for the solar park installation ($Mdn=4$, $IQR=4$), 47.33% of respondents showed generally positive affect towards it. After

conducting a one-way Welch ANOVA with Games-Howell post hoc tests,¹² it was further found that the affective reactions elicited by the wind park installation (Mdn=5, IQR=4.42, M=4.50) were significantly different from those elicited by solar rooftop installations (M=6.43, $p<0.001$), but not from those elicited by solar park installations (M=4.05, $p=0.09$). Independent t-tests further highlighted that affective reactions in this scenario are significantly different between the solar park and solar rooftop installations ($t=-14.69$, $p<0.001$).

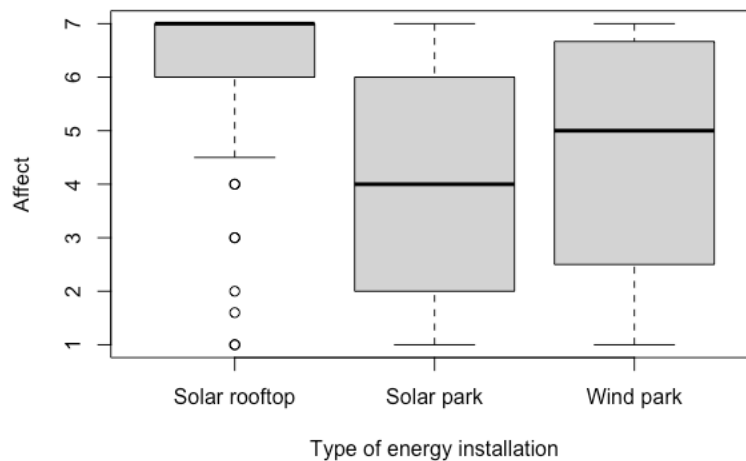


Figure 3: Boxplots of affect elicited by wind and solar energy in Scenario 1 (Alpine), displaying the median, 25th and 75th percentiles

Fig.4 shows the results of the affective reactions elicited in Scenario 2 (Midlands). The distributions of the affect elicited by wind park- (SD=1.92) and solar park (SD=1.92) installations are associated with similar standard deviations. It was further observed that for the solar park installation (Mdn=4.2, IQR=3), 50.25% of respondents showed overall positive affect. In contrast, 68.844% showed positive affect towards the rooftop installation in the same scenario (Mdn=5.2, IQR=2.5). Further, a one-way Welch ANOVA with Games-Howell post hoc tests¹³ showed that affective reactions elicited by the wind park installation (Mdn=4, IQR=3.5, M=3.89) are significantly different from those elicited by the solar rooftop installations (M=4.99, $p<0.001$), but not from those for solar park

¹² A Levene's test was significant at $p<0.001$. A Welch's ANOVA test was conducted ($F=143.46$, $df_1=2$, $df_2=350.02$, $p<0.001$) and was significant.

¹³ Levene's test was significant at $p=0.02$. Welch's ANOVA ($F=19.36$, $df_1=2$, $df_2=396.09$, $p<0.001$).

installations ($M=4.32$, $p=0.07$), similarly to the findings for Scenario 1 (Alpine). Independent t-tests further highlighted that affective reactions in this scenario are significantly different between the solar park and solar rooftop installations ($t=-3.70$, $p<0.001$).

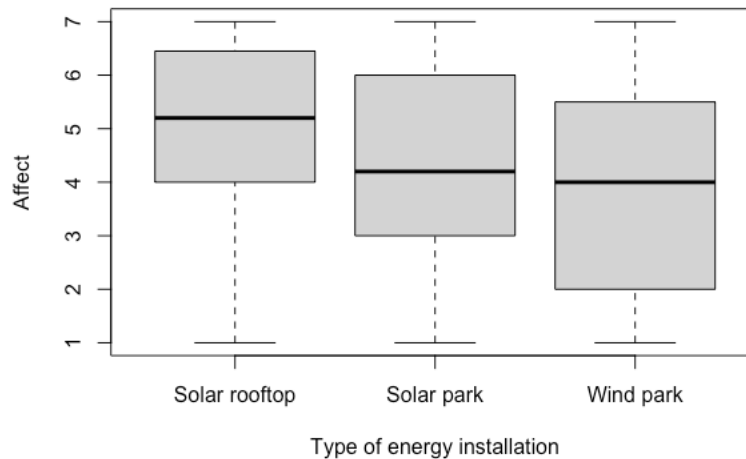


Figure 4: Boxplots of affect elicited by wind and solar energy in Scenario 2 (Midlands), displaying the median, 25th and 75th percentiles

4.4 The mediating role of affect in attitudes towards wind and solar energy infrastructures

Model 4 of the PROCESS macro for SPSS was used to investigate the role of feelings in the formation of attitudes towards the energy installations. Separate multiple regression analyses for each energy source and installation were also undertaken. This was done to measure the distinct effect of feelings on attitudes towards the energy infrastructure, as well as how this may differ from the general affect elicited by the energy source (solar versus wind energy) and the affect elicited by the installations while controlling for demographic variables.

To measure the potential mediating effect of feelings, the variables measured were first defined in the following way: attitudes towards the energy technologies as the dependent variable, the type of energy installation (1= wind park, 2=solar park, 3=solar rooftop) as the independent variable, and feelings elicited by the pictures as the mediating variable¹⁴.

¹⁴ In this case, I used the average of the feelings elicited in Scenario 1 and Scenario 2 to create a single measure for feelings.

In addition, the following variables were included as control variables: gender, age, political orientation, level of education, and place of residence (rural versus urban).¹⁵ Bias-corrected 95% bootstrap confidence intervals were subsequently used to evaluate the indirect effect of the type of energy installation on attitudes, which was found to be below zero, at -0.30 (-0.41 to -0.24). The type of energy installation had a direct effect on the feelings elicited, which, in turn, had an effect on attitudes. Therefore, a mediating effect of feelings on the relationship between the type of energy installation and attitudes was found (see Fig. 5).

An investigation of how affect and attitude may vary based on the size of the energy installation was also performed. Attitudes towards the solar rooftop and solar park installation were defined as dependent variables, type of installation (solar rooftop versus solar park) as independent variables, and feeling elicited by the energy technologies as the mediating variable. The same control variables were used as above. The confidence intervals used to evaluate the indirect effect of the size of the energy installation on attitudes was found to be below zero, at -0.64 (-0.84 to -0.46). The size of the energy installation had a direct effect on feelings elicited, which in turn, had an effect on attitudes. Therefore, a mediating effect of feelings on the direct relationship between installation size and attitudes was found (see Fig. 6).

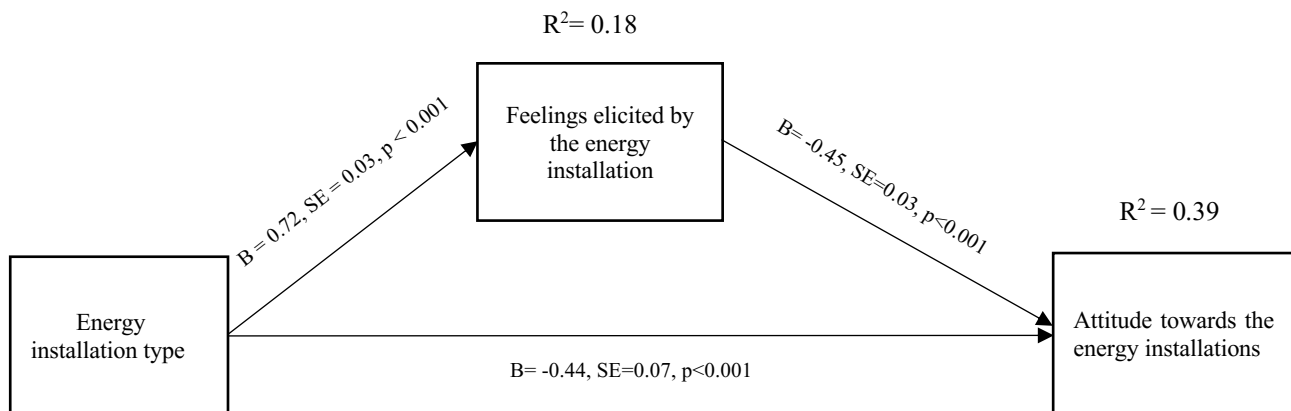


Figure 5: Feelings elicited by the energy installation mediate the relationship between the energy installation type and attitudes towards the energy installation (N=548).

¹⁵ The sample size for the analyses of Section 4.4 is n=548. Forty-nine respondents were excluded as they did not indicate allegiance to any specific party, or indicated a party other than one of the main seven Swiss political parties. Further, five respondents did not indicate whether they lived in a rural or urban area (one respondent did not have any allegiance to any specific party and did not indicate whether he lived in a rural or urban area).

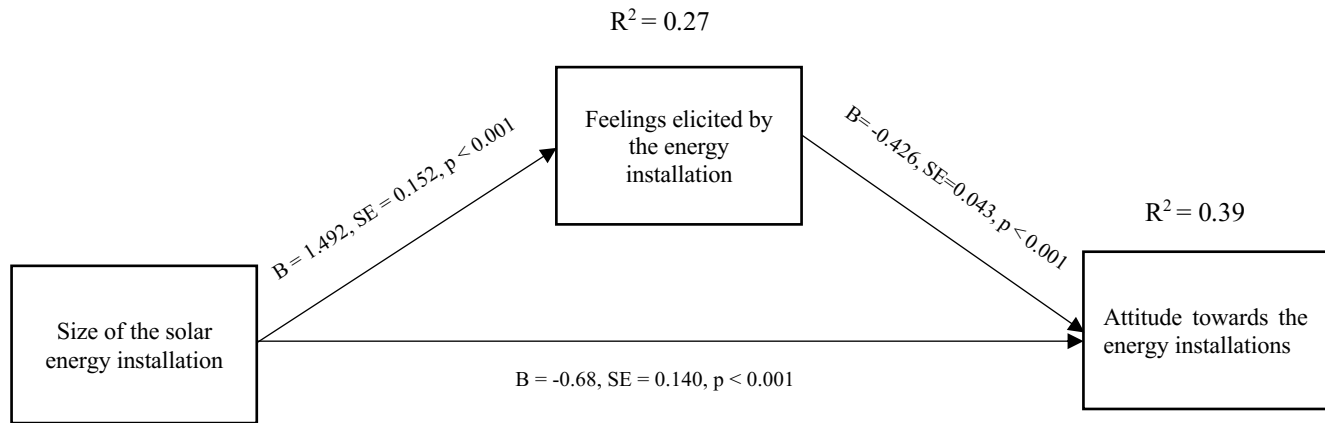


Figure 6: Feelings elicited by the size of the energy installation mediate the relationship between the size of energy installation and attitudes towards the energy installation (N=362).

Tables 2 and 3 present the results of the regression analyses. In Table 2, the effect of *general affect or feelings* on attitudes towards a wind park, solar park, or rooftop solar installation is highlighted. Affect was found to be significant,¹⁴ as well as the most important predictor of attitudes in all the regression models. The more negative the affect elicited, the higher the level of local concern. Specific to Models 1a to 1c, for which affect was measured at a general level, results show that affect had the highest level of significance in the case of attitudes towards a wind park ($B = -0.28, p < 0.001$) and the lowest in the case of attitudes towards a solar park ($B = -0.29, p = 0.004$). Overall, Model 1a, which predicts attitudes towards a wind park, explained 15.6% of the variance (adjusted R^2), 5% in the case of a solar park, and 12.4% in the case of a solar rooftop installation. Moreover, comparison of models 1b and 1c shows that the affect elicited by solar energy at a general level seems to have had a greater influence on attitudes towards solar rooftop installations ($B = -0.18, p < 0.001$) than solar park installations ($B = -0.26, p = 0.004$). Multiple regressions controlling for income were also run. The results are reported in Appendix E, in Tables E.1 and E.2. As with most surveys, about 15% of all observations are lost by controlling for income as respondents are often reluctant to report this. The robustness analysis shows that controlling for income has the following consequences on the model: First, in the case of Models 1b and 1c, general affect decreases in significance. Second, for Model 1b, the overall model becomes non-significant, while in Model 1c, the overall model

is still significant but at a lower. Overall, however, adding income does not impact the significant impact of general affect on attitudes.

Investigating the effect size (η_p^2) of feelings¹⁶ elicited by solar and wind energy in general on attitudes, it was further found that the former is greatest in the case of the wind park installation ($\eta_p^2 = 0.14$), and that the effect size is also larger in the case of the rooftop solar installation ($\eta_p^2 = 0.08$) than the solar park installation ($\eta_p^2 = 0.02$).¹⁷

	Wind park (Model 1a)				Solar park (Model 1b)				Solar rooftop (Model 1c)			
	B	SE	β	p-values	B	SE	β	p-values	B	SE	β	p-values
General affect	-0.28	0.06	-0.35	0.00	-0.26	0.00	-0.22	0.00	-0.18	0.05	-0.25	0.00
Gender	-0.01	0.21	-0.00	0.96	0.18	0.23	0.06	0.45	0.05	0.16	0.02	0.76
Age	0.03	0.07	0.03	0.67	0.08	0.08	0.07	0.32	-0.00	0.05	-0.00	0.98
Language region	0.65	0.22	0.21	0.00	-0.18	0.24	-0.06	0.45	-0.45	0.17	-0.19	0.01
Education	-0.21	0.22	-0.07	0.33	0.29	0.24	0.09	0.23	-0.15	0.17	-0.07	0.37
Political orientation	-0.09	0.12	-0.05	0.46	-0.06	0.12	-0.04	0.62	-0.21	0.09	-0.16	0.03
Place of residence	0.02	0.09	0.02	0.80	0.17	0.10	0.12	0.11	-0.04	0.06	-0.04	0.54
R ² adjusted	0.16				0.05				0.12			
F	5.85 (7, 177) ***				2.33 (7, 170)*				4.71 (7, 177)***			
Observations	185				178				185			

Note : for each type of energy infrastructure, a distinct multiple regression analysis was ran. B is the non- standardized regression coefficient. β is the standardized regression coefficient. SE is the standard error. General affect is specific to each energy source (i.e., wind and solar).

Table 2: Multiple regression results concerning attitudes with general affect

Table 3 presents the impact of affect elicited by each of the energy installations presented in the pictures, controlling for the demographic variables. In general, Models 2a-2c explain a higher share of the former than Models 1a-1c. This improvement may indicate that the closer the stimulus is to the object under consideration (i.e., the energy

¹⁶ In this case, affect was operationalized in the following way: 0= negative – for scores of 3 or lower; 1=neutral – for scores of 4; 2= positive – for scores of 5 or higher on the 7-point affective scale described in the methodology section.

¹⁷ According to Ellis (2010) and Cohen (1988), a partial eta square (η_p^2) of 0.01 corresponds to a small effect size, 0.06 to a medium effect size, and 0.14 to a large one.

infrastructure), the more powerful feelings are at predicting attitudes. The robustness analysis, including income, shows that the effect of income had no influence on the significance of affect on attitudes (see Appendix E).

Further, using eta squared (η_p^2), a large effect size in the case of the wind park ($\eta_p^2=0.2$) and the solar park ($\eta_p^2=0.16$) installations, and a medium effect size in the case of the solar rooftop installation ($\eta_p^2=0.13$)¹⁷ were found.

Moreover, in some instances, the sociodemographic variables were significant, but not as important in terms of predicting attitudes as affect. Interestingly, whether respondents were French- (=1) or German-speaking (=0) mattered in relation to attitudes towards wind park and rooftop solar installations with French-speaking respondents having a more negative attitude towards wind park installations than German-speaking ones, but a more positive one towards solar rooftop installations. Political orientation (1 = conservative, 2 = center-progressive, 3 = left-wing) had a significant effect in the case of rooftop solar installations, with respondents from more conservative political parties being more concerned. This contrasts with attitudes towards wind park and solar park installations, for which political orientation was not significant at all. Further, adding income, as reported in Appendix E, the significance of political orientation became less significant in the case of Model 1c, and was no longer significant in the case of Model 2c in terms of predicting attitudes towards solar rooftop installations.

	Wind park (Model 2a)				Solar park (Model 2b)				Solar rooftop (Model 2c)			
	B	SE	β	P-values	B	SE	β	P-values	B	SE	β	P-values
Constant	5.20	0.51		0.00	4.87	0.57		0.00	4.27	0.52		0.00
Affect–energy installation	-0.43	0.05	-0.52	0.00	-0.45	0.06	-0.53	0.00	-0.36	0.07	-0.36	0.00
Gender	-0.14	0.19	-0.05	0.43	0.24	0.21	0.08	0.25	0.05	0.15	0.02	0.79
Age	-0.04	0.07	-0.04	0.55	-0.08	0.07	-0.08	0.24	-0.04	0.05	-0.05	0.46
Language	0.59	0.20	0.19	0.00	0.16	0.22	0.05	0.47	-0.44	0.17	-0.18	0.01
Education	-0.09	0.20	-0.03	0.64	0.17	0.21	0.05	0.42	-0.17	0.16	-0.07	0.29
Political orientation	-0.12	0.11	-0.07	0.28	-0.13	0.11	-0.08	0.23	-0.19	0.09	-0.15	0.03
Place of residence	0.01	0.08	0.00	0.95	0.08	0.09	0.06	0.38	-0.00	0.06	0	0.99
R ² adjusted	0.29				0.28				0.18			
F	11.58*** (7,177)				16.40*** (7,170)				6.881*** (7,177)			
Observations	185				178				185			

Table 3: Multiple regression results concerning attitudes with the affect elicited by the energy installations

5. Discussion

As different countries are revising their energy strategies with the aim of decarbonizing the energy system, the acceptance of renewables at the community (local) level will be a key element in the success of this energy transition and proposed energy policies. Earlier literature that compared preferences for different renewable energy sources did not control for the size of installations when determining respondent preferences. However, lacking this approach, it is difficult to gauge which types of installations respondents were expressing their preferences for. Installation size appears to be critical, as it may amplify the visual impact of an energy installation on the landscape (namely, the change in landscape quality caused by the siting of the infrastructure) - which has been shown to be a dominant factor in the case of wind energy (Wolsink, 2007; Wolsink, 2018b). To address this gap and contribute to the research stream about the social acceptance of renewable

energy and more specifically how the generally high acceptance level (i.e., socio-political acceptance) of renewables may (may not) translate into a high acceptance level at the community level, the present study investigated how attitudes towards solar energy compare to attitudes towards wind energy, while controlling for the size of the installation. Further, to better understand what shapes differences in attitudes, the research described in this paper investigated the role of affect, a better understanding of which may help move beyond treating opponents of renewable installations as irrational individuals (Wolsink, 2018a; Aitken, 2010) by increasing understanding of their emotions.

5.1 Attitudes towards solar and wind energy installations: solar energy is not always preferred

A first novel finding pertains to attitudes towards solar and wind energy infrastructure when controlling for the size of the installations. In identical environments, results showed no statistically significant differences in attitudes towards solar and wind park infrastructure. On the other hand, individuals appeared significantly less concerned about the implementation of solar rooftop installations. This result indicates that comparing attitudes towards different technologies but not taking into account the size of infrastructure may reveal preferences that do not endure as the related technologies are deployed on a larger scale. This finding is important, as European energy policies have established clear targets for renewables, but the configuration of their deployment is not yet clear. The latter factor is particularly important as the transition from fossil fuels to renewables has resulted in the proliferation of new types of landscapes that are sometimes contested, spurring interest in the relation between land use and social acceptance (Leibenath & Lintz, 2018). In this regard, Wolsink (2018b) argues that local people and politics, not project developers, should take center stage in decisions about site selection and the use of land. The latter may be of particular relevance because renewable infrastructure is increasingly being deployed, and at a larger size, meaning that its visual impact is becoming more significant. Correspondingly, while in the case of Switzerland the population voted in favor of significantly increasing the share of national renewables through the Energy Strategy 2050, there is still hardly any awareness of what the implementation of this strategy means in

spatial terms (Wissen et al., 2019), while the active involvement of the latter in site selection may be critical in terms of the acceptance of the former (Wolsink, 2018b).

In sum, policymakers should be aware that despite the general high acceptance of renewables, there exists the risk that any technology, if deployed on a large scale, might face resistance. Specific to solar energy, solar parks may face resistance connected to the availability, use of land and visual impact that has already been identified in the case of wind parks (Wolsink, 2018b; Jäger-Waldau et al., 2020). On the other hand, solar rooftop systems do not occupy productive land (Jäger-Waldau et al., 2020). However, researchers have pointed out the crucial role of large-scale solar installations for achieving the European target of climate neutrality by 2050 (Hemetsberger, 2019), which in fact substantiates the importance of further investigating the social acceptance of large-scale solar installations and the related acceptance of the necessary land use in comparison to alternative uses, in addition to ownership structure, which has already been identified as a highly relevant factor (Wolsink, 2018a; Wolsink, 2018b; Busse & Siebert, 2018; Vuichard et al., 2021).

5.2 Solar energy: love decreases as the size of installations increases

Further, by comparing affective reactions to solar and wind energy on different levels (general vs. installation), and based on two different sizes of solar energy installation, the study produced novel findings in relation to the difference in perceptions about the two technologies. Specifically, when individuals think about solar and wind energy in general, with no further details provided about the two energy sources or the presentation of a specific project, the difference in affective reactions appear to reflect the differences in public attitudes observed in national polls, in which solar energy is greatly preferred over wind (Cousse & Wüstenhagen, 2018). However, when affect is measured in relation to specific items of energy infrastructure presented in identical settings, new relationships emerge. While affective reactions to solar rooftop installations are significantly more positive than for those to wind and solar park installations, affective reactions in relation to solar park and wind park installations are similar, and these results hold true with different background settings. As a result, the study highlights that affective reactions are not related to energy sources per se, but rather to infrastructure as well as the scale of the installation,

and thus provide a more nuanced picture about the previously identified “unanimously positive imagery of solar power” (Sütterlin & Siegrist, 2017, p.362).

5.3 The important role of affect in attitude formation regarding energy infrastructure

Another important element that arises from the analysis is that affect matters in developing attitudes towards an energy project. Feelings were found to have a mediating role in forming attitudes towards energy installations. Further, affect was the most relevant factor underlying attitudes towards a wind park, solar park, and solar rooftop installation. Specifically, the more positive the affect, the lower the level of concern about the implementation of the energy project.

Also interesting was the fact that when measured at a general level, affect had a larger effect on attitudes towards the implementation of a wind park than it did in relation to a solar park or solar rooftop installation. Also, affect elicited by solar energy in general appeared to be a better predictor of the acceptance of solar rooftop installations than solar parks. The conclusion is that individuals typically thought of solar rooftop installations when thinking about solar energy at a general level.

Further, the results highlighted that the regression models that included affect elicited by the solar and wind energy installations compared to solar and wind energy in general had greater explanatory power in terms of attitudes. This suggests that the more concrete an energy project appears to an individual, the more affect seems to matter in attitude formation. Additionally, the different sizes of the effect of affect on attitudes highlighted that the latter may matter more in the case of large-scale than small-scale installations. In the introduction, it was noted that Devine-Wright (2009) highlighted that the implementation of energy technologies may disturb emotional bonds to a place, and that we can expect that these bonds will be more strongly disrupted as the size of the energy infrastructure increases. The results seem to support this assumption. Debates concerning the implementation of energy projects may thus become increasingly emotionally loaded as the size of projects and the general deployment of renewable energy projects increases. In general, in line with earlier work (Wolsink, 1989; Sustainable Energy Ireland, 2003; Devine-Wright, 2007), the current study highlights a negative relationship between project

size and public support. The implication for policymakers is that, when possible, many small projects rather than a few large ones may be a more promising approach.

Finally, results show that French-speaking respondents are more concerned about the implementation of a wind park than German-speaking respondents, and the opposite holds true in the case of a solar rooftop installation. With more wind park projects in the planning phase in the French- than in the German-speaking part of Switzerland, a larger part of the French-speaking population may be in the second phase of the U-shaped curve – namely, the phase during which the population is most critical. Interestingly, however, no differences between the two language regions in the case of attitudes towards solar parks were identified. This may be caused by the low level of familiarity or experience of the Swiss population with solar parks.

5.4 Limitations and future research

As with any research paper, there are some limitations that can be the source for future research. First, the study focused on a specific geographical context. Switzerland shares many characteristics with other countries that have become engaged in the low-carbon energy transition, yet it also has specific characteristics that may affect the research findings, such as a relatively high per-capita income, no carbon-intensive domestic power generation, and a low density of solar and wind parks. It would be worthwhile investigating how attitudes to solar parks compared to those of wind parks vary in countries with different characteristics, especially in countries in which citizens are more familiar with solar park installations.

Second, the research measured affective reactions to solar and wind energy on an abstract level, as well as reactions to pictures of energy installations. However, debates concerning the implementation of energy projects are often emotionally loaded, not only because of the nature of the energy infrastructure or its visual impact on the landscape, but also because of how project developers tackle the projects (Cass & Walker, 2009). The current study investigated the acceptance of the public only and public opinion as part of the socio-political and community acceptance dimensions of the social acceptance triangle (Wüstenhagen et al., 2007). However, the concept of social acceptance of renewables is not only made up of mutually influencing processes at the three levels (community, socio-

political, market) but also involves different actors (project developers, policymakers, consumers) who are active at different levels (Wüstenhagen et al., 2007). Further studies could investigate how emotions are elicited and influenced in line with the different levels of the social acceptance triangle (Wüstenhagen et al., 2007). This calls for longitudinal research that could potentially contribute to the call of Wolsink (2018a) to recognize social acceptance as a “bundle of dynamic processes instead of a set of actors’ positions” (p.286).

Third, the aim of the study was not to predict individuals’ actual intentions to act against a specific renewable energy project, but rather to compare attitudes towards solar and energy projects in a hypothetical setting. Investigating the attitude formation process early on, however, may be very important for forecasting local acceptance or voting intentions (Mayer, 2007).

5.5 General conclusion and policy implications

Literature about the social acceptance of solar energy projects and specifically, large ones, is still scarce. Based on a representative survey in Switzerland (n=601), the present results reveal, through a comparison of small- and large-size solar power installations with wind power installations, that the more positive affective reactions and attitudes enjoyed by solar energy significantly decrease as the size of the two technologies is similar. While earlier studies consistently found that people prefer solar over wind power, the present study adds some nuance to these results and hints at the fact that while large solar projects may appear promising, they may face similar challenges with acceptance of the population at the local level as wind energy does. In fact, the results show that solar energy is not always preferred to wind energy, and suggests that policymakers should not only rely on public opinions polls to form the basis for policy decisions, as these may lead to distorted perceptions about the public support for renewable energy projects. They should also remain aware of how these general preferences may change depending on the size of the energy projects and their visual impact on the landscape (Wolsink, 2007; Wolsink, 2018b), and how these can affect people’s values and elicited emotions (positive or negative), in addition to other factors, such as distributional and procedural justice (Enevoldsen & Sovacool, 2016; Firestone et al., 2018; Walker et al., 2018) and place attachment (e.g.,

Smith & Marquez, 2000; Devine-Wright, 2009). Policymakers should not shy away from addressing the fact that solar energy installations may not easily be scaled up from a community acceptance perspective, as is also the case with other technologies deployed on a large scale. For example, policymakers who hope they can avoid controversy by avoiding wind energy and prioritizing solar energy (Hochstrasser, 2018) may encounter similar problems with large-scale solar, or fail to meet the renewable energy targets defined in their national energy policies. Policymakers should thus consider social acceptance issues in general and, more specifically, acceptance at the local level, and think about how to diversify the energy mix to mitigate the risk of opposition. The current results also highlight the tension involved in choosing between the deployment of decentralized versus centralized renewable energy systems, as well as the related level of acceptance of the land use required for renewable energy systems weighed against alternative uses.

Findings further show that affect is an important factor underlying attitudes towards the implementation of solar parks, wind parks, and rooftop solar installations, and that affect elicited by pictures of energy infrastructures has a larger effect on attitudes in the case of large-scale installations. Further, the study highlights that affect elicited by solar energy in general is a weaker predictor of attitudes towards solar parks than towards rooftop solar installations. This supports earlier research (Sütterlin & Siegrist, 2017) that found that individuals imagine small solar PV installations when thinking about solar energy at a general level, perhaps explaining the gap in public attitudes between wind and solar that is found in national surveys. Taken together, the findings show that as the deployment of renewables significantly increases to make Europe carbon neutral by 2050, policymakers and project developers may increasingly have to attend to the emotions elicited by energy infrastructure among the population during the different phases of the development of energy projects, and improve their communication. Attempts by policymakers or project developers to convey rational knowledge about the benefits of renewable energy projects may not lead to the intended behavioral outcomes unless emotional components are taken into account. Moreover, in relation to attitudes towards renewables, policymakers should be aware that there exists the risk that any technology, if deployed on a large scale, might face resistance, even if public attitudes are initially overwhelmingly positive.

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Appendix

Appendix A: Survey items

The following table lists survey items used to create the variables. Please note that the survey was fielded in German and French. The following is the English translation of the original survey.

Variable	Survey item wording	Response scale
(1) Imagery/associations elicited by solar and wind energy at a general level	“What are the first thoughts or images that come to your mind when thinking of solar/wind energy?”	1 to 5 association listed
(2) Affective evaluations of the associations measured at a general level	“What are your feelings regarding the thought or images you provided about wind/solar energy?” <i>Please use the scale below to evaluate your feeling from very negative to very positive. Each thought or image needs to be evaluated separately.</i>	1-7 [very negative - very positive]
(3) Imagery/associations elicited by pictures of solar and wind energy installations	“What are the first thoughts or images that come to your mind when looking at this picture ?”	1 to 5 association listed
(4) Affective evaluations of the associations elicited by the pictures	“What are your feelings regarding the thought or images you provided about the picture?” <i>Please use the scale below to evaluate your feeling from very negative to very positive. Each thought or image needs to be evaluated separately.</i> <i>Please indicate the extent to which you agree with the following statement:</i>	1-7 [very negative - very positive]
(5) Local concern	“I would be concerned if a wind park / solar park / solar rooftop installation would be built in my neighbourhood or other places, I feel close to”.	1 (totally disagree) to 5 (totally agree) 6 (I do not know/no opinion)
(6) Gender	<i>n/a</i>	Male = 0 ; Female = 1
(7) Age	<i>n/a</i>	Integer 1 = ≤ 29
(8) Age group	<i>n/a</i>	2 = 30-45 3 = 45-59 4 = ≥ 59

Note: The questions on affective imagery (1-4) are based on Peters and Slovic (1996). Questions 1 and 5 were asked in a similar form in Cousse et al. (2020)

Appendix A: Survey items table

Variable	Survey item wording	Response scale
(9) Language region	<i>n/a</i>	0 = German-speaking 1 = French-speaking
(10) Education	<i>n/a</i>	0 = no high school diploma 1 = high school diploma or higher
(11) Political orientation	<i>n/a</i>	1 = "Conservative" (SVP, FDP, CVP) 2 = "Center-progressive" (BDP, GLP) 3 = "Left-wing" (SP, GPS) 0 = no or other political party
(12) Place of residence	"Where do you currently live?"	1= city centre 2= suburbs 3= agglomeration 4= countryside 5= no answer

Appendix A: Survey items table (cont.)

Appendix B: Images presented to the respondents according to the treatment group

Treatment group	Scenario 1: Alpine	Scenario 2: Midlands
1. Solar park		
2. Solar rooftop		
3. Wind park		

Note: Pictures of solar park, solar rooftop and wind park installations presented to the respondents based on their treatment group. (Felix Brönimann and author's figures, 2019)

Appendix B: Images presented to the respondents according to the treatment group

Appendix C: Characteristics of the sample.

	“Wind park” group n = 201	“Solar park” group n = 197	“Solar rooftop” group n = 203	Total sample n = 601	Swiss population
Age					
15-29	17.90%	19.30%	18.20%	18.50%	23%
30-39	11.90%	17.30%	14.30%	14.50%	18%
40-49	19.90%	17.80%	22.20%	20.00%	19%
50-59	21.40%	19.80%	15.30%	18.80%	20%
60-74	28.90%	25.90%	30.00%	28.30%	20%
Gender					
♂	53.70%	49.70%	46.80%	50.10%	49%
♀	46.30%	50.30%	53.20%	49.90%	51%
Education					
low/medium	63.20%	61.90%	64.00%	63.10%	62%
high	36.80%	38.10%	36.00%	36.90%	38%
Political Orientation					
“Conservative” (SVP, FDP, CVP)	59.70%	53.30%	59.10%	57.40%	57%
“Center- progressive” (BDP, GLP)	9.50%	5.10%	9.40%	8.00%	9%
“Left-wing” (SP, GPS)	23.40%	32.50%	23.60%	26.50%	26%
Others/none	7.50%	9.10%	7.90%	8.20%	8%
Language region					
French-speaking	32.30%	38.60%	31.50%	34.10%	27%
German- speaking	67.70%	61.40%	68.50%	65.90%	73%

Note: Sources for the data about the Swiss population: Age (BFS, 2018a) , Gender (BFS, 2018a), Political Attitude (BFS, 2018a), and Language region (BFS, 2018b).

Appendix C: Characteristics of the sample.

Appendix D: Descriptive statistics

	Mean	S.D.	Min.	Max.	N
<i>Average affect</i>					
Affect towards solar (general)	5.74	1.83	1 (very negative)	7 (very positive)	601
Affect towards wind (general)	4.49	1.45	1 (very negative)	7 (very positive)	601
Affect towards solar park (S ₁)	4.05	2.05	1 (very negative)	7 (very positive)	197
Affect towards solar park (S ₂)	4.32	1.92	1 (very negative)	7 (very positive)	197
Affect towards wind park (S ₁)	4.50	2.18	1 (very negative)	7 (very positive)	201
Affect towards wind park (S ₂)	3.89	1.92	1 (very negative)	7 (very positive)	201
Affect towards solar rooftop (S ₁)	6.43	1.04	1 (very negative)	7 (very positive)	203
Affect towards solar rooftop (S ₂)	4.99	1.68	1 (very negative)	7 (very positive)	203
<i>Socio-demographic variables</i>					
Age	3.24	1.47	1 (<29)	4 (>59)	601
Gender	0.50	0.50	0 (male)	1 (female)	601
Education	0.37	0.48	0 (low/medium)	1 (high)	601
Language region	0.34	0.47	0 (German)	1 (French)	601
Political Orientation	1.66	0.90	1 ("Conservative")	3 ("Left-wing")	552
Income	1.95	0.84	1 (<6'000 CHF)	3 (>9'000 CHF)	512
Place of residence	2.97	1.17	1 (City center)	4 (Countryside)	596

Note: S.D. stands for "standard deviation".

Appendix D: Descriptive statistics table

Appendix E: Regression analyses including income

The analysis reported in Tables E.1 and E.2 is for assessing the sensitivity of the results to the inclusion of the income variable. As is well known for survey research, many respondents prefer not to answer income-related questions. This survey is not an exception with overall about 15% of respondents who preferred not to report their income levels. Acknowledging the potential source of biases in the coefficient estimates due to these dropped observations, this section nevertheless reports the regression results with the income variable (corresponding to Models 1a – 2c of the main specification in Tables 2-3). The estimated coefficients of income themselves turn out statistically not significant and the coefficients that were significant before are only slightly affected both in terms of their estimated magnitude and the confidence levels.

	Wind park (Model 1a')				Solar park (Model 1b')				Solar rooftop (Model 1c')			
	B	SE	β	p-value	B	SE	β	p-value	B	SE	β	p-value
General affect	-0.26	0.06	-0.32	0.00	-0.22	0.10	-0.19	0.02	-0.12	0.06	-0.17	0.04
Gender	-0.18	0.23	-0.06	0.44	0.19	0.26	0.06	0.46	-0.03	0.17	-0.02	0.84
Age	0.00	0.08	0.00	0.97	0.07	0.08	0.07	0.41	0.05	0.06	0.06	0.45
Language region	0.65	0.25	0.21	0.01	-0.17	0.26	-0.05	0.53	-0.51	0.19	-0.21	0.01
Education	-0.20	0.25	-0.07	0.42	0.13	0.26	0.04	0.61	-0.14	0.19	-0.06	0.45
Political orientation	-0.06	0.14	-0.04	0.64	-0.06	0.13	-0.04	0.65	-0.19	0.10	-0.15	0.06
Place of residence	0.02	0.10	0.01	0.86	0.19	0.11	0.14	0.09	-0.01	0.07	-0.01	0.91
Income	-0.17	0.142	-0.10	0.23	0.08	0.15	0.05	0.58	0.13	0.11	0.10	0.22
R ² adjusted	0.13				0.02				0.09			
F	3.84***				1.44				2.85**			
Observations	153				156				160			

Appendix E.1: Multiple regression results concerning attitudes with general affect - controlling for income scale.

	Wind park (Model 2a')				Solar park (Model 2b')				Solar rooftop (Model 2c')			
	B	SE	β	p-value	B	SE	β	p-value	B	SE	β	p-value
Affect–energy installation	-0.43	0.06	-0.50	0.00	-0.46	0.06	-0.55	0.00	-0.39	0.07	-0.42	0.000
Gender	-0.30	0.21	-0.10	0.15	0.37	0.22	0.12	0.10	-0.06	0.16	-0.03	0.69
Age	-0.08	0.08	-0.07	0.32	-0.04	0.08	-0.04	0.54	-0.03	0.06	-0.04	0.63
Language region	0.60	0.23	0.19	0.01	0.23	0.24	0.07	0.34	-0.43	0.17	-0.18	0.02
Education	-0.10	0.23	-0.03	0.68	0.07	0.23	0.02	0.77	-0.23	0.18	-0.10	0.20
Political orientation	-0.10	0.12	-0.06	0.42	-0.14	0.12	-0.09	0.21	-0.15	0.09	-0.11	0.11
Place of residence	0.02	0.09	0.0	0.79	0.10	0.10	0.07	0.32	0.05	0.07	0.06	0.45
Income	-0.17	0.13	-0.10	0.19	0.13	0.13	0.04	0.55	0.09	0.10	0.07	0.36
R ² adjusted	0.27				0.25				0.21			
F	8.17***				7.58***				6.30***			
Observations	153				156				160			

Appendix E.2: Multiple regression results concerning attitudes with the affect elicited by the energy installations - controlling for income scale.

Paper III

Tell me how you feel about geothermal energy¹:

Affect as a revealing factor of the role of seismic risk on public acceptance

Julia Cousse^{2,3}, Evelina Trutnevyte⁴, Ulf J.J. Hahnel⁵

Abstract

Social acceptance of renewables, such as geothermal energy, is a key factor in successfully meeting national energy targets. Siting geothermal projects can be challenging because of induced seismicity related to deep geothermal energy, which may not only reduce public acceptance of deep geothermal projects but also of less risky shallow geothermal projects. The study investigates the role of seismic risk on affect, emotions, and attitudes towards shallow and deep geothermal projects. Two between-subjects experimental studies were conducted with representative samples of the Swiss population ($N_1=1,018$; $N_2=1,007$). Results show that information about seismic risks of deep geothermal energy significantly influences perception of associated projects. A spillover effect of seismic risk information on shallow geothermal projects is observed for affect and emotions as well as for risks and benefits perceptions, but not for attitudes. Spillover effects were stronger when the information about seismic risk was presented in a negative, emotionally laden manner. For policymakers, the results suggest that the population is open to the use of both shallow and deep geothermal energy, but early communication will be key to avoiding a decline in acceptance. The study also highlights the importance of measuring affective in addition to cognitive factors in acceptance research.

Keywords : Deep geothermal energy, Shallow geothermal energy, Acceptance, Induced seismicity, Emotions, Affect

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1. Introduction

Many countries are defining long-term goals to transform their energy systems to limit greenhouse gas emissions. Implementation of these goals requires taking public preferences into account, as public attitudes have become increasingly important in energy system planning and implementation (Wüstenhagen et al., 2007; Blumer et al., 2018). However, the formation of public attitudes in relation to the energy transition is a complex process shaped by many factors at various levels (Wüstenhagen et al., 2007; Batel and Devine-Wright, 2015). Examples from different countries have shown that public opposition can considerably delay, or even stop, the deployment of energy projects, especially of wind (Walker et al., 2018; Batel, 2020) and deep geothermal energy (Wallquist and Holenstein, 2012; Reith et al., 2013; Benighaus and Bleicher, 2019).

In a report on renewable energy, the Intergovernmental Panel on Climate Change (IPCC) stated that geothermal energy has “the potential to provide long-term, secure base-load energy and GHG emissions reductions” (Goldstein et al., 2011, p.404). In Switzerland, the Swiss Energy Strategy 2050 aims that deep geothermal energy production contributes up to 7% of the country’s future electricity demand in the longer run (Hirschberg et al., 2015; Dubois et al., 2019). Further, shallow and medium-depth geothermal projects with district heating can greatly contribute to decarbonizing the country’s heating sector (Narula et al., 2019; Pratiwi and Trutnevyte, 2021). Despite its greenhouse gas (GHG) reduction potential, there is still little understanding of how people perceive geothermal energy as well as underlying drivers to the acceptance of this technology compared to other renewables (Pellizzzone et al., 2015; Volken et al., 2017; Knoblauch et al., 2019). However, based on experience with other energy technologies (e.g., wind energy), a good understanding of public’s affective reactions elicited by energy technologies (e.g., Jobin et al., 2019; Cousse et al., 2020b) is crucial to anticipate signs of public concern and subsequently be able to mitigate the risk of opposition.

Further, research has pointed out that the public seems to confuse shallow geothermal energy with deep geothermal energy, potentially leading to unfounded resistance to shallow geothermal projects (Dubois et al., 2019). This confusion may arise from a spillover effect where the risks related to deep geothermal energy influence the perception of an associated technology, namely shallow geothermal energy. In the context of geothermal energy, seismic risk associated with deep geothermal projects has been at the forefront of public debate

(Giardini, 2009; Stauffacher et al., 2015; Rfj, 2020). However, the actual risk and impact associated with shallow geothermal projects compared to that of deep geothermal projects is significantly lower or even non-existent (Trutnevyte and Wiemer, 2017; Wiemer et al., 2017). Further, although affect and emotions are important for explaining public support for energy technologies (e.g., Truelove, 2012; Perlaviciute et al., 2017; Cousse et al., 2020b; Huijts and Van Wee, 2015), affective responses elicited by geothermal energy are still under-researched (Zaunbrecher et al., 2018; Dubois et al., 2019). Currently, policymakers and project developers often struggle to handle people's emotional responses to energy projects in an adequate way (Cass and Walker, 2009). Common responses to negative emotions of the population include simply continuing with a project, neglecting emotions, or immediately stopping a project even after major investments has been made (Perlaviciute et al., 2018). Incorporating affect and emotions into acceptance research may help to better understand drivers of public acceptance of geothermal projects, in turn helping policymakers and project developers in crafting new strategies for managing various elements of public acceptance such as emotions and thus support the implementation of renewable energy projects.

Based on these considerations, the present research investigates the effect of information about seismic risk related to deep geothermal projects on affect, discrete emotions, attitudes, and perceived risks and benefits of deep geothermal project *and* shallow geothermal projects. In the current study, affect is distinguished from discrete emotions. The latter relates to specific emotional experiences such as anger, or pride while affect is defined as a person's general positive or negative feelings towards a specific stimulus (e.g., geothermal energy) (Leiserowitz, 2006). Additionally, this research examines how presenting information about seismic risk in a neutral versus a more negative, emotionally laden, manner may affect the target outcomes, thus covering the different communication frames used to describe geothermal projects. In this way, in the current study we investigate beyond the link between affect, emotions and attitudes elicited by geothermal energy by investigating their underlying drivers including perceived risks and benefits (see e.g., Slovic and Peters, 2006). Accordingly, the following research questions were developed:

1. *How does affect towards geothermal energy change depending on whether individuals are informed about the seismic risk of deep geothermal projects using neutral or negative framing?*
2. *Does information about seismic risk associated with deep geothermal projects spill over to attitudes and discrete emotions towards shallow geothermal projects?*
3. *What are the perceived risks and benefits of geothermal energy, and how do they vary based on provided information about seismic risk?*

Methodologically, the research is based on two complementary experimental studies in Switzerland with representative samples of the population ($N_1 = 1'018$; $N_2 = 1'007$). Specifically, in Study 1, information about seismic risk was presented in a neutral manner, while in Study 2 information was presented in a more negative and emotionally laden manner, similarly to communication about geothermal energy in public debates and the media. Study 2 also included additional measurements to explore the perceived risks and benefits of geothermal energy. Specifically, respondents of Study 2 had to evaluate perceived risks and benefits of geothermal energy reported by respondents of Study 1. All other elements remained similar between the two studies.

2. Background

2.1 Social acceptance of geothermal energy and risk communication

Geothermal energy projects face similar opposition to that associated with other energy-related infrastructures. Previous research has highlighted that even individuals who are generally supportive of renewables do not support them without condition, leading to a difference in acceptance between the general and the so-called local levels (Joe et al., 2016). While on a general level, the Swiss population would like to have at least 8% of the Swiss electricity mix come from geothermal energy (Volken et al., 2018; Cousse et al., 2020a), deep geothermal projects face opposition at the local level (Rfj, 2020). In Switzerland, the perceived association between earthquakes and geothermal energy may have been intensified

in public discourse based on experiences with domestic geothermal projects. Two deep geothermal pilot projects in the cities of Basel and St. Gallen in the last decade caused earthquakes, leading to minor damage to buildings (Edwards et al., 2015; Trutnevyte and Wiemer, 2017). Since these events, geothermal energy has been mainly discussed in terms of risk by the Swiss media (Stauffacher et al., 2015; Ejderyan et al., 2019). More recently, an earthquake which occurred in South Korea, as a result of induced seismicity related to a deep geothermal project made the headlines in Swiss media (Grigoli et al., 2018; Rfj, 2020), and it caused further challenges in terms of public and political acceptance for an ongoing Swiss deep geothermal project in Haute-Sorne, Jura. Acceptance-related issues concerning geothermal energy are not limited to Switzerland, but exist in Germany (Benighaus and Bleicher, 2019), Australia (Dowd et al., 2011), France (Chavot et al., 2016) and Italy (Pellizzone et al., 2015). These challenges have sparked research aimed at understanding public perceptions about geothermal energy exploitation (Leucht, 2012; Stauffacher et al., 2015).

Research has found that people have no established preferences towards deep geothermal energy as it is still a relatively unknown technology (Blumer et al., 2018). Dubois et al. (2019) and Volken et al. (2018) revealed that preferences for deep geothermal energy significantly decrease when respondents are informed about the technology's potential impacts, as opposed to the case of solar PV or wind. On the other hand, Knoblauch et al. (2019) and Stadelmann-Steffen and Dermont (2016) found that the use of heat pumps has a positive influence on the perception of geothermal energy, in general.

How people perceive risk is important because the perception influences individual behavior and the acceptance of energy technologies (Gupta et al., 2012; Siegrist and Árvai, 2020). Regarding risk communication, Ejderyan et al. (2019) identified that it is damaging for project developers, political authorities, and scientists to downplay the risk perceived by the population about geothermal energy. Instead, the population's concerns should be better understood and attended to. According to the approach of mental models (Morgan, 2002), risk communication should start with "strategic listening" (Pidgeon and Fischhoff, 2011); that is listening to relevant stakeholders to understand their knowledge, perceptions, and needs. Upon these elements, more deliberated communication strategies can be designed.

Recent events have shown that earthquakes caused by deep geothermal projects may affect the local acceptance of deep geothermal projects even if the seismic events occurred in geographically distant regions (Grigoli et al., 2018; Rfj, 2020). Further, the spillover effect of seismic risk associated with deep geothermal energy on the acceptance of shallow geothermal projects is yet unclear. Given the potential of geothermal energy to contribute to the decarbonization of the energy sector (Goldstein et al., 2011), signs of public concern should be anticipated and addressed in a timely and constructive manner to mitigate the risk of opposition.

2.2 The role of feelings and emotions in social acceptance of energy technologies

The affective component of decision-making has received some attention within the research stream of the social acceptance of energy technologies and more broadly, energy-related decisions. Studies which have investigated the affective side of energy-related decisions have empirically shown that emotion-related variables have an explanatory power in relation to energy-related decisions that is additional to that of models that include only cognitive variables (Brosch et al., 2014; Hahnel and Brosch, 2018).

Specific to energy technologies research has illustrated that affect and emotions matter for decisions regarding various energy projects and their acceptance (e.g. Truelove, 2012; Jobin et al., 2019). In this regards, affective imagery⁶ has been used to measure the relationship between individuals' perceptions of energy technologies and acceptance (Truelove, 2012; Sütterlin & Siegrist, 2017; Cousse et al., 2020b). Using this technique, Truelove (2012) and Cousse et al. (2020b) both found that affect is highly correlated with acceptance of wind energy. Sütterlin and Siegrist (2014) used the same methodology to investigate the affect elicited by solar energy and found that the public associate solar power with highly positive imagery. Cousse (2021) further showed that affect plays an especially important role concerning large energy installations. Jobin et al. (2019) found that affective reactions to energy technologies influence both, the way they search for information as well as their

⁶ Affective imagery is a methodology used to uncover the affective influences in decision-making (Leiserowitz, 2006). Respondents are first asked to list their spontaneous associations regarding a stimulus (e.g., "geothermal energy"). Subsequently, they are asked to rate the associations they provided on an affect scale.

energy technology preferences. Further, Huijts and Van Wee (2015) showed that affect also matters regarding public acceptance of hydrogen fuel stations and Emmerich et al. (2020) revealed that affect has a mediating role in the acceptance of various technologies.

With regards to the role of emotions, researchers have highlighted that different emotions of the same valence (e.g., anger and fear) can lead to different behavioral responses (Lerner & Keltner, 2001; Lerner & Keltner, 2000). Based on this, Huijts (2018) investigated the factors that influence anger, fear, joy, and pride evoked by hydrogen fuel stations, and found that people feel angrier when they perceive more procedural and distributional unfairness, while environmental benefits and local utility caused individuals to feel a higher amount of joy.

Further, previous research indicated that it is difficult to change individuals' feelings about a technology once initial impressions have been formed, even when knowledge about that technology is limited (Bruine de Bruin and Wong-Parodi, 2014). Indeed, as first impressions are affective, they can be created based on little to no knowledge, but guide cognition and perception of risks and benefits (e.g., Poortinga and Pidgeon, 2004). Moreover, studies have shown that individuals who are suspicious of a technology tend to apprehend new information about this technology more negatively (Bruine de Bruin and Wong-Parodi, 2014). Similarly, initial preferences influenced the extent to which people evaluated information about a large-scale energy program as personally relevant (Hahnel et al., 2020).

While these studies provide interesting insights and have been crucial in showing that affect and emotions matters in decision-making, we still have little insights into underlying factors to the acceptance of geothermal energy and more specifically, into how affect and emotions influence the latter. Based on this, the current paper extends on the literature on risk perceptions by measuring how a risk (i.e., seismic risk) about a technology (i.e., deep geothermal energy) influences perception (spillover effect) of another related technology (i.e., shallow geothermal energy). In particular, we examine how affect induced by the potential seismic risk of deep geothermal projects influences affect, emotions and perceived risks and benefits of shallow geothermal projects (Peters and Slovic, 2006) providing policymakers and project developers avenues to effectively communicate between different stakeholders of geothermal projects.

3. Study 1: large-scale survey (n=1'018) with neutral information about seismic risk

3.1 Methodology

3.1.1 Survey design

We applied a between-subjects experimental study design to analyze the effect of informing respondents about induced seismicity caused by *deep* geothermal projects on overall attitudes, affect, discrete emotions, and the perceived risks and benefits of *shallow* and *deep* geothermal projects. The study was based on two between-subjects experimental factors: provision of *seismic risk information* in a neutral way (absent/present) and *type of project* evaluated by participants (*deep* geothermal/*shallow* geothermal). This second factor allowed us to test whether a spillover effect of awareness about seismic risk from *deep* geothermal projects to *shallow* geothermal projects can be observed. Importantly, in the information provided about seismic risk, it was stressed that the seismic risk was related to past *deep* geothermal projects whereas *shallow* geothermal projects were not mentioned. The summary of the survey flow can be found in Appendix A, Figure A.1, which depicts the information provided to participants in the four experimental conditions. Figure 1 highlights the information provided about: (1) geothermal energy in general (presented to all respondents), (2) seismic risk related to *deep* geothermal projects (presented only to respondents randomly assigned to receive information about seismic risk), (3) a hypothetical *shallow* and *deep* geothermal project (respondents saw one of the two, depending on which group they were randomly assigned to).

General information about geothermal energy

Please read the following information on geothermal energy:

Geothermal energy is the heat of the Earth. The deeper we go into the earth's crust, the higher the temperature rises. The energy geothermal energy is **renewable** and can be **used locally**. In this way, it contributes to increasing **Switzerland's energy independence**. It also provides energy with low CO₂ emissions and therefore low impact on the climate. Unlike other renewables, geothermal energy does not depend on climatic conditions, season or time of day. It is **available in 24 hours a day, 365 days a year**.

Experimental factor 1 (seismic risk information): Information about seismic risk related to deep geothermal projects (neutral framing)

Please read the following information on two previous deep geothermal projects in Switzerland:

In Basel, in 2006, a **deep geothermal energy** project that reached a depth of **5'000m** underground had to be abandoned after pilot tests triggered an earthquake of magnitude 3.6 on the Richter scale. In 2013, another pilot project in St. Gallen with a depth of **4'500m** caused an earthquake of magnitude 3.4. Although drilling operations resumed after the St. Gallen earthquake, the project was interrupted due to a lack of hot water flow. In both cases, the earthquake caused only minor property damage.

Experimental factor 2 (project type) – condition 1: Information about the hypothetical shallow project

In Switzerland, geothermal energy production is in its infancy. In the coming years, geothermal energy projects are planned in various cantons. You will be asked to evaluate a hypothetical project.

Imagine that your local energy supplier is planning a **shallow** geothermal project, which reaches up to **60m** below the surface of the earth. The project is expected to produce the equivalent of the **annual heating and hot water demand of 200 households**. The plant will supply a district heating network. The district heating network functions as a large central heating system for an entire neighborhood and replaces individual radiators, making the **heating system more efficient**.

Experimental factor 2 (project type) - condition 2: Information about the hypothetical deep project

In Switzerland, geothermal energy production is in its infancy. In the coming years, geothermal energy projects are planned in various cantons. You will be asked to evaluate a hypothetical project.

Imagine that your local energy supplier is planning a **deep** geothermal project that would reach **5'000m** below the surface of the earth and would cover the equivalent of the **annual electricity needs of about 2'500 households**. In addition to the electricity produced, the geothermal power plant would also supply a heating network, equivalent to the **annual heating and hot water consumption of 15'000 households**. The district heating network functions as a large central heating system for an entire neighborhood and replaces individual heaters, making the **heating system more efficient**.

Figure 1: Information provided to respondents in Study 1.

3.1.2 Recruitment of survey participants and sample characteristics

The survey was conducted online and programmed using the software package Unipark⁷. The data were collected between January and February 2020 through a market research agency⁸. Survey invitations were stratified according to geographical region, age, gender, political orientation, and education in order to match the distribution of these variables in the Swiss population. In total, 1'192 respondents completed Study 1⁹, out of which 174 observations were omitted. The final sample consisted of 1'018 respondents. Exclusion was based on the following indicators: (i) clicked-to-complete, i.e., choose the same answer to every question; (ii) answer provided in open-text field was not intelligible (e.g., dots); and (iii) failed the control question¹⁰. Table B.1, in Appendix B reports the summary statistics for the main demographic variables. The four groups were balanced; ANOVA tests showed that the groups were, on average, not statistically different in relation to demographic variables

3.1.3 Measurements

Attitude towards the geothermal project (shallow or deep) was measured by asking, “Would you rather be for or against the project if it was implemented close to your place of residence?” Respondents could choose between five different options: against (1), rather against (2), neutral/no opinion (3), rather in favor (4) or in favor (5).

Familiarity with geothermal energy was measured by asking “Have you ever heard of geothermal energy?” Respondents who had never heard about geothermal energy before (N=269) were excluded from the analysis related to Research question 1 as their initial affect about geothermal energy could not be measured.

Initial affect towards geothermal energy (pre-information) was measured before respondents received any information about geothermal energy and was only asked to respondents who indicated they had heard about geothermal energy before (N=749). We used

⁷ <https://www.unipark.com/en/>.

⁸ Intervista AG (<https://www.intervista.ch/?lang=fr>). The panel consists of 100'000 registered Swiss individuals who have been actively recruited through Intervista.

⁹ Completion rate of 74.2%

¹⁰ Respondents failing to answer correctly the following question were excluded from the survey: “Please select the word *Energy* from the list below.”

the affective imagery technique (e.g., Leiserowitz and Smith, 2017) to measure initial affect. This technique is interesting as it provides an easy and efficient way to determine people's free associations regarding a particular object and minimizes the researcher bias through using an open-ended assessment technique (Leiserowitz and Smith, 2017). Using this technique, we asked "What are the first thoughts or images that come to your mind when you think of geothermal energy?" In response, respondents had to provide at least one, and a maximum of five or brief statements. The respondents thereafter evaluated each of their associations in terms of their valence on a 7-point affect scale, from "very negative" to "very positive." As such, the affective images collected contain two elements: a cognitive component (the image or thought elicited) and an associated affective rating (positive or negative) (Smith and Leiserowitz, 2014). The initial affect variable was calculated by computing the mean of the evaluations for the provided associations.

Affect about geothermal energy (post-information) was measured by asking: "What is your overall feeling about the proposed project?" Answer options ranged from "very negative" to "very positive" on a 7-point affect scale.

Self-reported knowledge about geothermal energy was measured before any information about geothermal energy was provided by asking "How would you evaluate your knowledge of geothermal energy?" The scale ranged from "no knowledge" to "very good knowledge" on a 7-point Likert scale. A score of "1" corresponded to a low level of knowledge (<4), a score of "2" to an average level (=4), and a score of "3" to a high level (>4).

Discrete emotions about the project: Discrete emotions (worried, enthusiastic, angry and proud) towards the project were measured by asking: "What emotions do you feel when you think about the implementation of the described geothermal project in the proximity of where you live?" Answers were administered on a 7-point Likert scale ranging from "not at all" to "very strongly".

Argumentation to support or oppose the project: After indicating their attitude towards the project, respondents were asked to briefly explain their decision in an open-text field. Answer to this question was not mandatory.

3.2 Data analysis and results of Study 1

3.2.1 Research Question 1: Effect of seismic risk information on affect about geothermal energy

We started by investigating how affect towards geothermal energy changed depending on whether respondents have been informed about the seismic risk of deep geothermal projects. We first controlled whether the experimental groups vary in their initial affect towards geothermal energy. An ANOVA with the between-subjects factors *seismic risk information* (present/absent) and *type of evaluated project* (*deep* geothermal/*shallow* geothermal) and initial affect towards geothermal energy as dependent variable showed no baseline difference in affect towards geothermal energy (effect seismic information condition $F(1, 745) = 1.85$, $p = .174$, $\eta_p^2 = .002$; effect project condition: $F(1, 745) = 0.163$, $p = .686$, $\eta_p^2 = .00$).

Then, we conducted an ANCOVA with the two between-subjects factors and initial affect towards geothermal energy as covariates. Affect towards geothermal energy after information presentation served as dependent variable. The means and standard errors of affect towards geothermal energy for the four experimental conditions are depicted in Figure 2, indicating an increase in positive affect after general information presentation about geothermal energy. ANCOVA findings revealed a significant main effect of *seismic risk information* ($F(1, 744) = 6.82$, $p = .009$, $\eta_p^2 = .01$) and *type of project* ($F(1, 744) = 6.61$, $p = .010$, $\eta_p^2 = .01$) on affect. As indicated by a significant interaction of both factors ($F(1, 744) = 8.52$, $p = .004$, $\eta_p^2 = .01$), the effect of *seismic risk information* on affect was dependent on whether participants evaluated a *deep* or *shallow* geothermal project. That is, whereas *information about seismic risk* resulted in less positive affect when participants evaluated a *deep* geothermal project ($M_{dif} = 0.62$; $t(366) = 3.63$, $p < .001$), this information did not influence affect when participants evaluated a *shallow* geothermal project ($M_{dif} = .43$; $t(379) = .43$, $p = .665$). This indicates that no spillover effect of *seismic risk information* on shallow geothermal energy projects occurred.

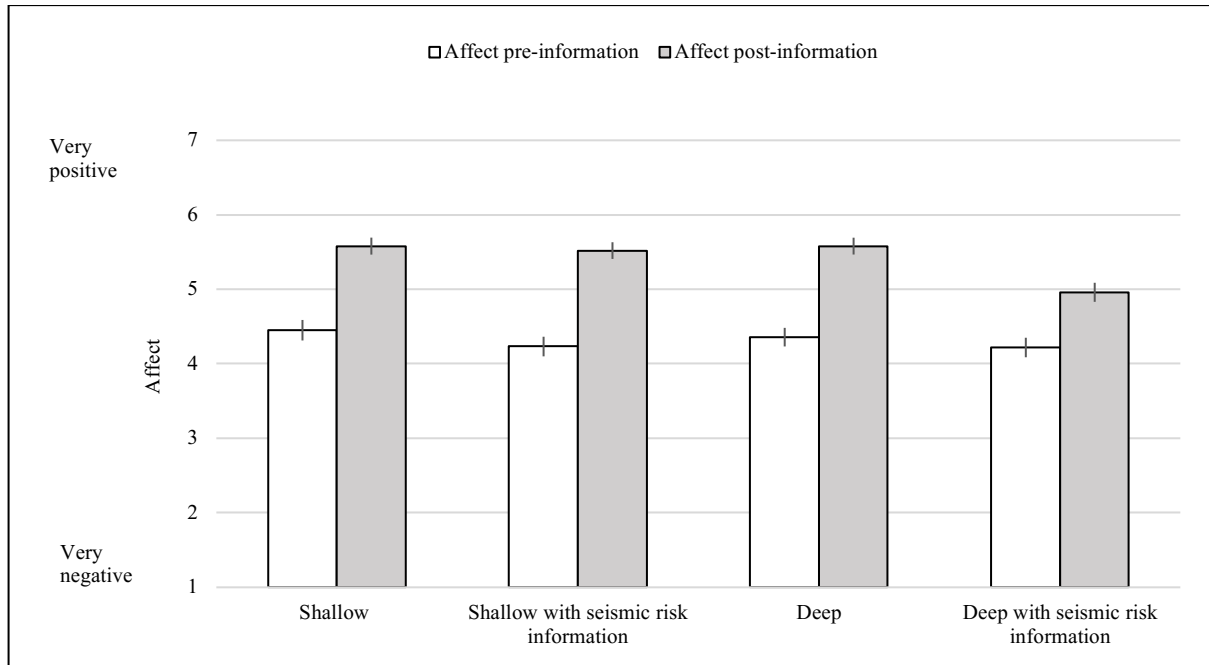


Figure 2: Affect towards geothermal energy (pre/post general information) for the four experimental conditions in Study 1. Affect pre-information refers to affect toward geothermal energy in general as measured by the affective imagery technique. Affect post-information refers to affect towards the presented geothermal project (shallow/deep). Error bars depict standard errors of means.

Next, we tested whether the observed changes in affect towards geothermal energy were subject to participants' *self-reported knowledge* and their *initial level* of affect (before information provision), while controlling for the experimental factors. To this end, we computed a difference score, reflecting changes in affect pre-post general information about geothermal energy. An ANOVA with the difference score as dependent variable showed that *self-reported knowledge* impacted changes in affect ($F(2, 737) = 6.86, p = .001, \eta_p^2 = .02$). Specifically, the change in affect of respondents who considered their knowledge about geothermal energy to be (rather) high was significantly smaller than for those who evaluated it as average ($M_{dif} = -.58, p = .007$) or low ($M_{dif} = -.57, p = .001$, Bonferroni correction for all differences).

Regarding the role of initial affect, an ANOVA with *initial affect* (negative/positive)¹¹ as additional factor showed a significant main effect of this factor on affect change ($F(1, 616) = 250.42, p < .001, \eta_p^2 = .29$) in that increases in positive affect were stronger for participants

¹¹ A score of "1" corresponds to a negative initial affect (<4), a score of "2" to positive initial affect (>4). Respondents who had an initial neutral affect ($=4$) were excluded from this analysis ($n=125$).

with initial negative affect as compared to participants with initial positive affect. Figure 3 visualizes affect ratings as a function of participants' *initial affect* and the experimental conditions.

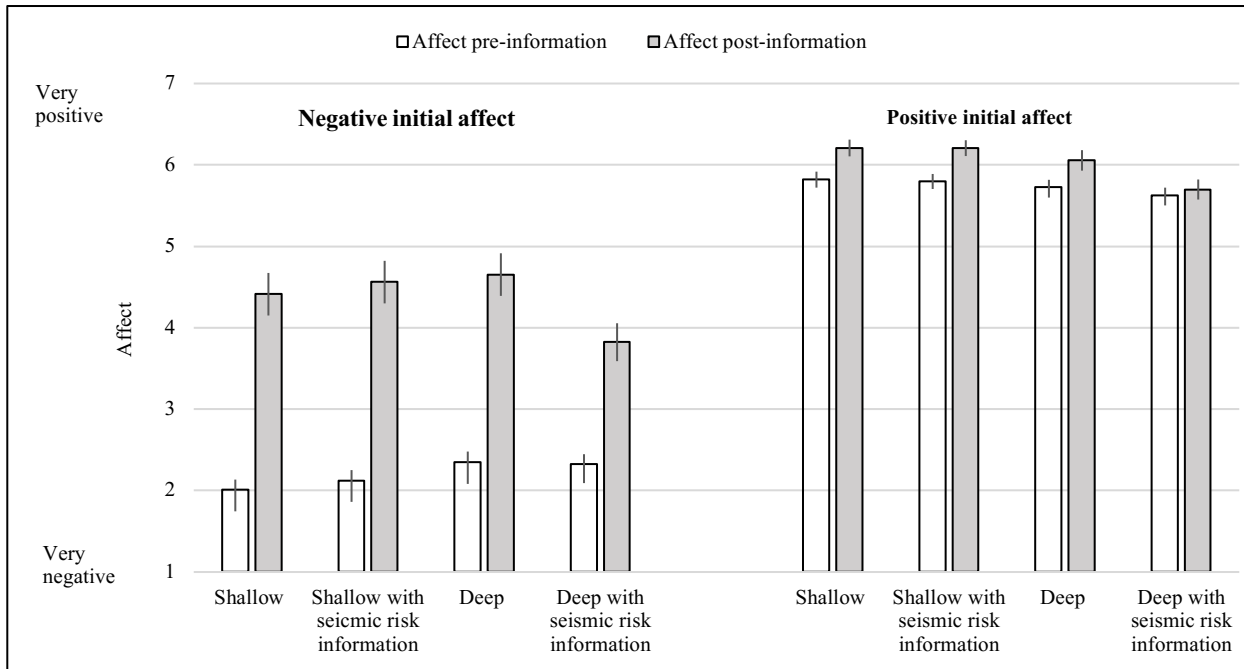


Figure 3: Affect towards geothermal energy (pre/post general information) for the four experimental conditions in Study 1. Segmented based on the initial affect valence. Affect pre-information refers to affect toward geothermal energy in general as measured by the affective imagery technique. Affect post-information refers to affect towards the presented geothermal project (shallow/deep). Error bars depict standard errors of means.

3.2.2 Research Question 2: Effect of seismic risk information on attitudes and emotions towards geothermal projects

Research question 2 investigates the impact of *seismic risk information* on attitudes towards *shallow* and *deep* geothermal projects and the emotions elicited by the technology. To measure the effect on attitudes, we conducted an ANOVA in which *seismic risk information* (absent/present) and type of evaluated project (*deep* geothermal/*shallow* geothermal) served as factors, and attitudes towards geothermal energy projects as the dependent variable. The analysis showed that the impact of *seismic risk information* was subject to whether participants evaluated a *deep* or *shallow* geothermal energy project (interaction of *seismic risk information* and *type* of project: $F(1, 1014) = 4.79, p = .03, \eta_p^2$

=.01). In line with the findings on affect, whereas *seismic risk information* resulted in less positive attitudes when participants evaluated a *deep* geothermal project ($M_{dif} = -0.41$, $p < .001$), this information did not influence attitudes when participants evaluated a *shallow* geothermal project ($M_{dif} = -0.10$, $p = .716$), thus not indicating a spillover effect of seismic risk information on attitudes towards shallow geothermal energy projects.

Whereas analyses of overall affect and attitudes did not indicate spillover effects, analysis of discrete emotions showed that *seismic risk information* overall increased worry ($F(1, 1014) = 13.90$, $p < .001$, $\eta_p^2 = .01$) and decreased enthusiasm ($F(1, 1014) = 20.13$, $p < .001$, $\eta_p^2 = .02$) and pride ($F(1, 1014) = 12.20$, $p < .001$, $\eta_p^2 = .01$) towards *deep* and *shallow* geothermal projects. As such, this effect was not specific to deep geothermal projects (interaction of *seismic risk information* and *type of project*: $F(4, 1011) = 1.11$, $p = .349$, $\eta_p^2 = .00$), pointing to a spillover effect of *seismic risk information* from *deep* to *shallow* geothermal projects for discrete emotions.

4. Study 2: large-scale survey (n=1'007) with negative, emotionally laden information about seismic risk

4.1 Methodology

4.1.1 Survey design

The design of Survey 2 was similar to that of Survey 1 except that the information about seismic risk was presented in a more negative, emotionally laden way (see Figure 4 for provided information and Tables D.1 and D.2, in Appendix D for perceived valence of the information). The general information about geothermal energy and the information about the hypothetical geothermal project were identical in both studies (see Figure 1 in Section 3.1.1 for more information). Further, as opposed to Study 1, Study 2 investigated Research Question 3: “What are the perceived risks and benefits of geothermal energy, and how they vary based on provided information about seismic risk?”. A summary of the survey flow of Study 2 can be found in Appendix A, Figure A.2.

Experimental factor 1 (seismic risk information): Information about seismic risk related to deep geothermal projects (negative framing)

Please read the following information on three previous deep geothermal projects:

In Basel, in 2006, a **deep geothermal energy** project that reached a depth of **5'000m** underground had to be abandoned after pilot tests triggered an **earthquake** of magnitude 3.6 on the Richter scale. This resulted in **damages to buildings** equivalent to **CHF 8-10 million**. In 2013, another pilot project in St. Gallen with a depth of **4'500m** caused an earthquake of magnitude 3.4. Although drilling operations resumed after the St. Gallen earthquake, the project was interrupted due to a lack of hot water flow. More recently, in 2017, an **earthquake of magnitude 5.4** was caused by deep geothermal testing in South Korea, one of the **most devastating** in the country since 1905. The earthquake had **disastrous consequences: 135 people were injured; 290 million Swiss francs of damage were caused** (in many cases to residential buildings) and more than 1000 people had to leave their homes and live in temporary shelters. In this case, the **deep geothermal** project posed an **immediate threat to humans, nature and the economy**.

Figure 4: Information about seismic risk provided in survey 2; All other experimental conditions, were similar to survey 1.

4.1.2 Recruitment of survey participants and survey characteristics

Recruitment of participants was similar to that of Survey 1. Data was collected in October 2020 by a different market agency.¹² In total, 1'041 respondents completed survey 2¹³, of whom 34 observations were excluded. The final sample consisted of 1'007 respondents. Exclusion was based on the following indicators : (i) clicked-to-complete, i.e., chose the same answer to every question; or (ii) answer provided in open-text field was not intelligible (e.g., dots). Similarly to Study 1, the sample compares well with the Swiss population with respect to age, gender and political orientation (see Appendix B, Table B.2 for more information).

¹² <https://innofact-marktforschung.de/en/>

¹³ Completion rate of 83.82%.

4.1.3 Measurements

In addition to the measures described in Section 3.5 for Survey 1, the following measures were implemented in Survey 2:

Manipulation check: To ensure that the information provided in Study 2 about seismic risk was indeed more negative, we asked “How would you evaluate the text you have just read?”

¹⁴ Responses could be provided using a 7-point scale from “very negative” to “very positive.”

Thought listing about the project: To obtain deeper insights into what may motivate a respondent to favor or reject a geothermal project, we used a thought-listing procedure elaborated by Hardisty et al. (2010). Specifically, we asked “Would you be rather for or against the project if it was carried out close to where you live (city, village, town)? Before answering this question, please give us all your thoughts as you consider this decision. Please list below all the thoughts, both positive and negative, that come to your mind as you consider your decision about the geothermal project near your place of residence.” Next, participants indicated their attitude towards the project (see *attitude towards the geothermal project in Section 3.1.3*). Participants then responded to their own thought listings and classified each as to whether it *supported* the project, *opposed* it, or had *no influence*. Based on this, we undertook a qualitative analysis of the thoughts elicited by the geothermal projects among respondents. We focused the analysis on respondents whose initial affect towards geothermal energy was negative (<4) (see Section 4.2.1). To this end, we coded the thoughts that these respondents provided and indicated themselves as being in favor of the project. Ninety-eight thoughts supporting the projects emerged from this process, which could be attributed to 23 different categories, excluding “other” (see Appendix E, Table E.2).

Evaluation of risks and benefits of geothermal energy: Participants were asked to evaluate a list of statements by participants of Survey 1 who had been asked to explain their decision regarding the geothermal project in an open text field. Specifically, in Survey 2, we asked: “Please indicate the extent to which you agree with the following statements about the geothermal project that was presented to you. If you have no opinion at all about one of the statements, you can skip the statement and move on to the next one. Please note that not all

¹⁴ This question was only asked to respondents who were informed about seismic risk.

statements are *correct* in a scientific sense.” The scale ranged from “fully disagree” to “fully agree” on a 7-point scale. The full statements can be found in Table E.1, in Appendix E. We compared the evaluation of statements according to whether respondents had been informed about seismic risk or not and according to whether the statements could be considered as being related or not to the information that had been provided about seismic risk¹⁵.

4.2 Data analysis and results

4.2.1 Research question 1: Effect of seismic risk information, presented in a more negative, emotionally laden manner, on affect about geothermal energy

As in Study 1, we did not observe baseline differences in affect towards geothermal energy between the experimental groups prior to information provision (*seismic risk information*: $F(1, 742) = 0.58, p = .447, \eta_p^2 = .001$; *type of project*: $F(1, 745) = 3.127, p = .077, \eta_p^2 = .004$). In order to examine our research question we conducted, identical to Study 1, an ANCOVA with the between-subjects factors *seismic risk information* (present/absent) and *type of project* (*deep* geothermal/*shallow* geothermal), initial affect towards geothermal energy as covariate and affect towards geothermal energy after general information presentation as dependent variable. Findings show a significant main effect of *seismic risk information* ($F(1, 741) = 71.27, p < .001, \eta_p^2 = .09$) and *type of project* ($F(1, 741) = 16.44, p < .001, \eta_p^2 = .022$). In contrast to Study 1, the effect of *seismic risk information* was not specific to deep geothermal projects (two-way interaction of *seismic risk information* x *type of project*: $F(1, 741) = 1.36, p = .244, \eta_p^2 = .002$). That is, information about seismic risk resulted in less positive affect when participants evaluated a *deep* geothermal project ($M_{dif} = 0.941; t(379) = 5.80, p < .001$) as well as when participants evaluated a *shallow* geothermal project ($M_{dif} = .771; t(363) = 4.895, p < .001$). The results suggest that the presentation of emotionally laden information (Study 2) compared to neutral information (Study 1) increases the likelihood of spillover effects in that *seismic risk information* about *deep* geothermal projects also decreases affect towards *shallow* geothermal projects (see Figure 5).

¹⁵ For example, feeling worried (or not) about seismic risk can be associated with the information provided about seismic risk, but agreeing (disagreeing) that geothermal energy can increase energy independence is not related to the information provided.

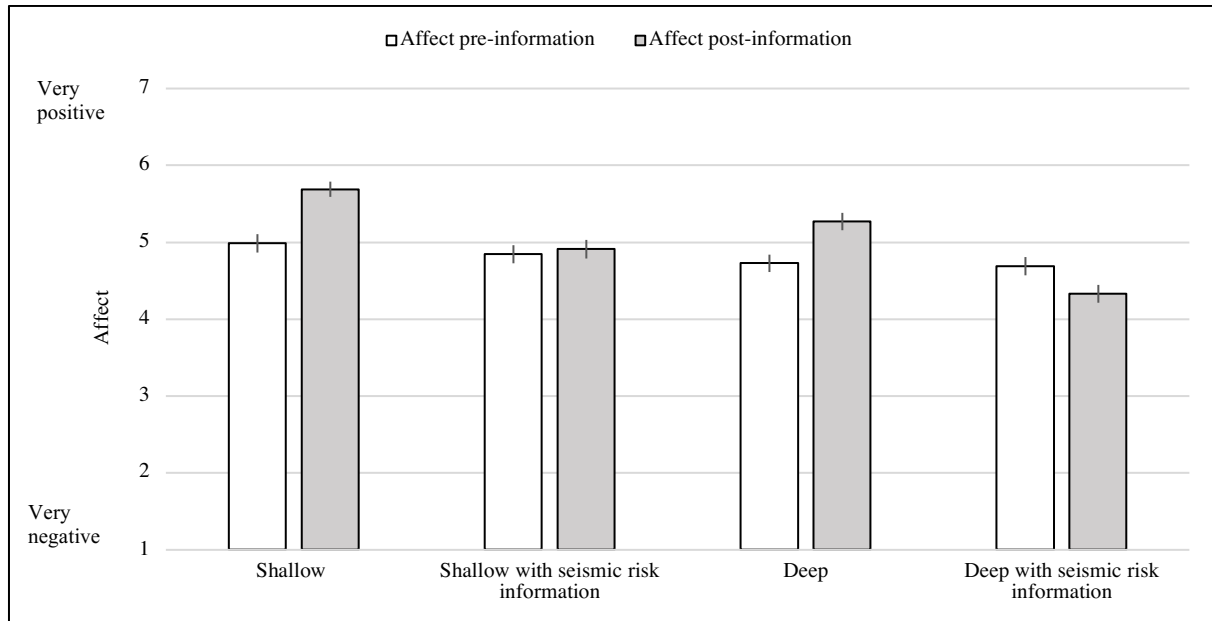


Figure 5: Affect towards geothermal energy (pre/post general information) for the four experimental conditions in Study 2. Affect pre-information refers to affect toward geothermal energy in general as measured by the affective imagery technique. Affect post-information refers to affect towards the presented geothermal project (shallow/deep). Error bars depict standard errors of means.

Next, as in Study 1, we segmented respondents according to whether their affect was initially negative or positive and ran an ANOVA, adding *initial affect* as a factor and the difference score of affect pre-post information as dependent variable (see Study 1). The results show a significant main effect of *initial affect* on affect change ($F(1, 635) = 127.14, p < .001, \eta_p^2 = .17$), in that, similarly to Study 1, increases in positive affect was stronger for participants with initial negative affect as compared to participants with initial positive affect (See Figure 6)¹⁶. In contrast to Study 1, we find that more negative information about seismic risk had a significant negative impact on respondents' affect. Specifically, for participants who had an initial positive affect, it is indicated that those who were informed about seismic risk became significantly more negative independent of whether they evaluated a *deep* ($M_{dif} = -0.85; t(120) = -5.63, p < .001$) or *shallow* geothermal project ($M_{dif} = -0.40; t(122) = -2.78, p < .006$) compared to the baseline.

¹⁶ Respondents who had an initial neutral affect (=4) were excluded from this analysis (n=103).

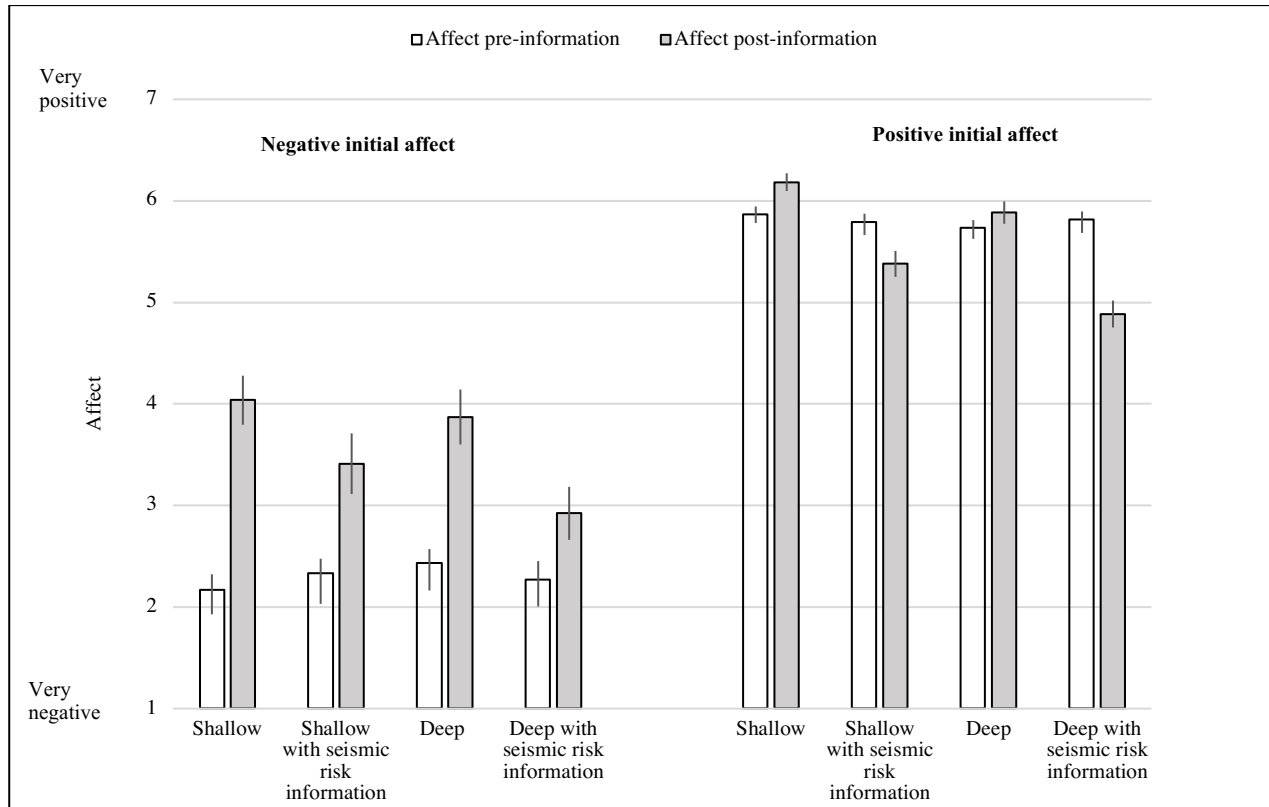


Figure 6: Affect towards geothermal energy (pre/post general information) for the four experimental conditions in Study 2. Segmented based on the initial affect valence. Affect pre-information refers to affect toward geothermal energy in general as measured by the affective imagery technique. Affect post-information refers to affect towards the presented geothermal project (shallow/deep). Error bars depict standard errors of means.

4.2.2 Research question 2: Effect of seismic risk, presented in a more negative, emotionally laden manner, on attitudes and emotions

Next, we aimed to test whether providing information about seismic risk in a more negative, emotionally laden manner, causes a spillover effect of seismic risk information on attitudes and discrete emotions towards shallow geothermal projects. To analyze effects on attitudes, as in Study 1, we conducted an ANOVA with the factors *seismic risk information* (absent/present) and *type of evaluated project* (deep geothermal/shallow geothermal) and the dependent variable attitudes towards geothermal energy. The analysis showed that the impact of *seismic risk information* on attitudes was subject to whether participants evaluated a *deep* or *shallow* geothermal energy project (interaction of *seismic risk information* and *type of project*: $F(1, 1003) = 12.71, p = .002, \eta_p^2 = .01$). That is, contrary to the findings on affect (see

Section 4.2.1), while information about seismic risk resulted in less positive *attitudes* when participants evaluated a *deep geothermal* project ($M_{dif} = -.71, p < .001$), this information did not influence *attitudes* when participants evaluated a shallow geothermal project ($M_{dif} = -.26, p = .073$).

While analyses of attitudes did not indicate a spillover effect, analysis of discrete emotions showed that *seismic risk information* overall increased worry ($F(1, 1003) = 80.18, p < .001, \eta_p^2 = .07$) and decreased enthusiasm ($F(1, 1003) = 72.92, p < .001, \eta_p^2 = .07$) and pride ($F(1, 1003) = 38.71, p < .001, \eta_p^2 = .04$) towards both *deep* and *shallow* geothermal projects (interaction of *seismic risk information* and *type of project*: $F(4, 1003) = 1.66, p = .158, \eta_p^2 = .01$), similarly to Study 1. In addition to Study 1, we also found that *seismic risk information* overall increased anger ($F(1, 1003) = 52.21, p < .001, \eta_p^2 = .05$) for both *types* of projects. These results indicate a spillover effect of *seismic risk information* from *deep* geothermal projects to *shallow* geothermal projects for discrete emotions, and also that presenting information about seismic risk in a more negative, emotionally laden manner can increase anger towards both *shallow* and *deep* geothermal projects.

4.2.3 Research question 3: Perceived risks and benefits of geothermal energy and the effect of seismic risk

This section responds to Research Question 3, namely, how information about seismic risk framed more negatively impacts the evaluation of risks and benefits of geothermal energy. With regards to the *shallow* geothermal project, we find that *seismic risk information* significantly increases the perception that the technology is not mature enough ($M_{dif} = .44; t(497) = 2.9, p < .004$), which can be considered as closely related to the information provided about seismic risk. On the other hand, we also observed that providing seismic risk information does not only impact perceptions of the actual technology, but also impacts the perception of the role of geothermal energy in the energy transition. Specifically, it decreases the perceived benefit of *shallow* geothermal projects in terms of energy independence ($M_{dif} = -.54; t(496) = -3.58, p < .001$), but also in terms of phasing out fossil fuels and compensating for the phasing out of nuclear energy ($M_{dif} = -.68; t(488) = -4.54, p < .001$) (See Figure 7). In the case of the *deep* geothermal project (see Figure 8), the effect of seismic risk information on perceived risks and benefits is even stronger. Specifically, *seismic risk information* had a

significant effect on the evaluation of a wider range of statements for respondents who evaluated the deep geothermal project. In terms of statements related to the information about seismic risk, we find that the latter significantly increases concern about seismic risk ($M_{dif} = 1.02$; $t(497) = 6.72$, $p < .001$), the perception that the technology is not mature enough ($M_{dif} = 1.00$; $t(495) = 6.88$, $p < .001$), that one's region is more prone to earthquakes ($M_{dif} = .51$; $t(487) = 3.21$, $p < .001$), and unease about the idea of drilling into the ground ($M_{dif} = .62$; $t(499) = 3.81$, $p < .001$). Regarding statements not related to seismic risk, we find that being informed about seismic risks has a significant negative effect on the perceived benefit of geothermal energy in terms of energy independence ($M_{dif} = -.88$; $t(496) = -5.95$, $p < .001$) and compensating for phasing out fossil fuels ($M_{dif} = -.76$; $t(492) = -4.99$, $p < .001$) and nuclear energy ($M_{dif} = -.53$; $t(497) = -3.37$, $p < .001$).¹⁷ Also, respondents who were informed about seismic risks and who evaluated a *deep* geothermal project were more worried about potential water contamination from geothermal energy production ($M_{dif} = .57$; $t(497) = .76$, $p < .001$), and believed that solar ($M_{dif} = .6$; $t(493) = 4.41$, $p < .001$) and wind ($M_{dif} = .57$; $t(495) = 4.14$, $p < .001$) energy are better alternatives to geothermal energy compared to those not informed.

¹⁷ Switzerland is planning to gradually phase out the use of nuclear energy:
<https://www.bfe.admin.ch/bfe/en/home/policy/energy-strategy-2050/what-is-the-energy-strategy-2050.html>

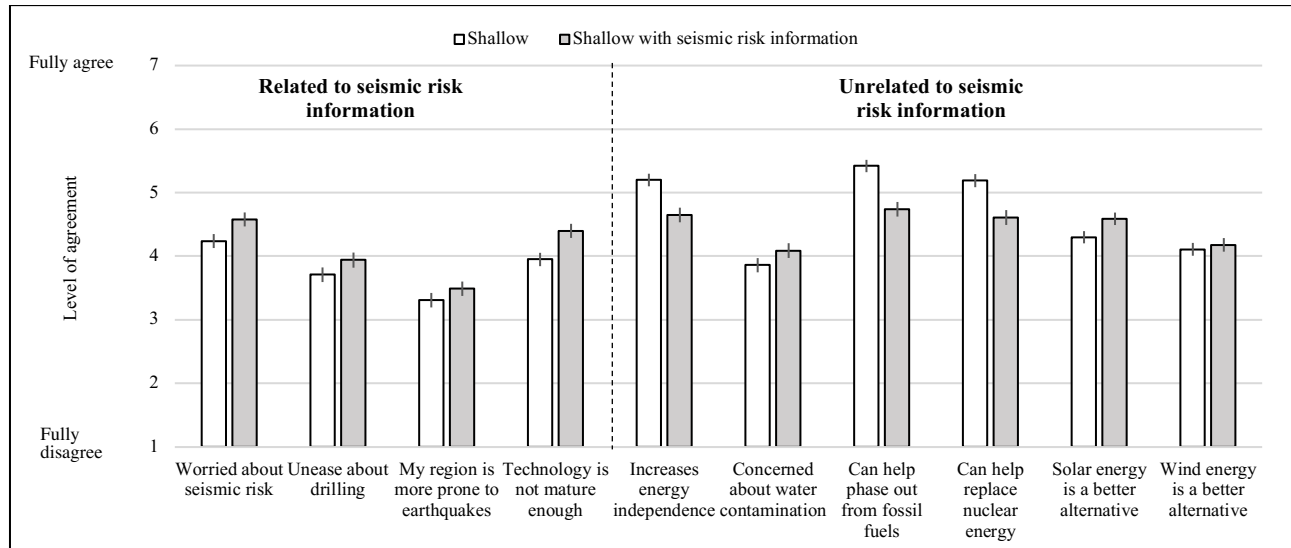


Figure 7: Direct and indirect consequences of seismic risk on perceived risks and benefits of geothermal energy as a function of seismic risk information (present/absent) for participants evaluating a shallow geothermal energy project. Error bars depict standard errors of means.

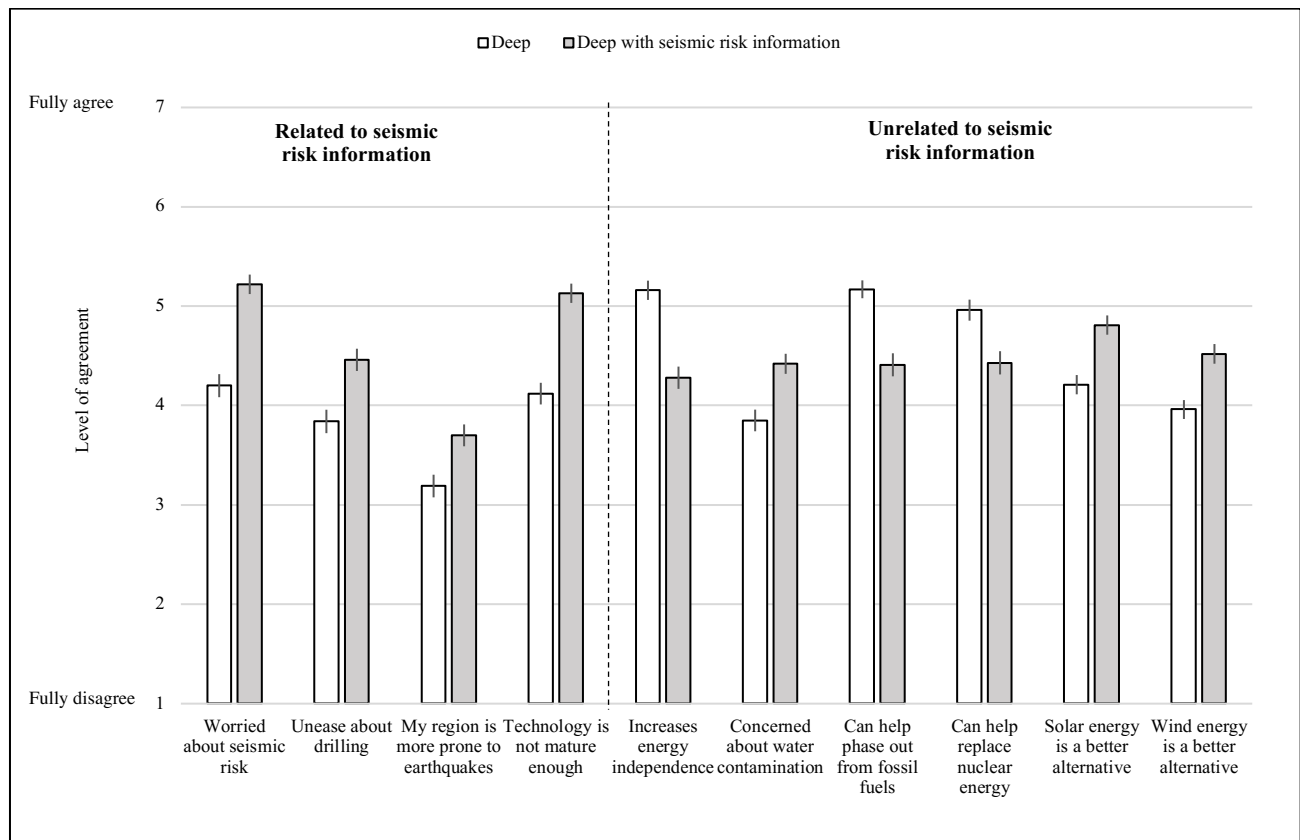


Figure 8: Direct and indirect consequences of seismic risk on perceived risks and benefits of geothermal energy as a function of seismic risk information (present/absent) for participants evaluating a deep geothermal energy project. Error bars depict standard errors of means.

In Section 4.2.1, we found that respondents who started off with initially negative affect towards geothermal energy became significantly more positive about it after receiving information about the technology. To better understand this phenomenon, we conducted a more in-depth qualitative analysis of the thoughts of respondents who had an initial negative affect towards geothermal energy (see Section 4.1.3 for the details). The full results are illustrated in Table E.2, in Appendix E. In Figure 9, we outline the most important categories in each group according to their relative frequency.¹ We first observe that the perceived benefit for the environment appears to be a key thought in favor of geothermal projects, except for respondents who had to evaluate a *deep* geothermal project and were informed about its seismic risk. Second, we find that whether seismic risk can be controlled seems to be an important element that may make respondents who were initially negative about the technology feel more positive about it. Third, it appears that respondents who were informed about the seismic risk related to deep geothermal projects and had to evaluate a shallow geothermal project, reacted positively to the low depth of the shallow project as highlighted in the project description. Fourth, for the two groups who were informed about seismic risk, respondents appear to be in favor of the project based on the rationale that one must learn from their mistakes. Additionally, the results show that the main benefits perceived from *shallow* geothermal projects are energy independence and cost savings, as well as the view that it can be a good alternative for the future.

¹ For groups 1-3, Categories 3 and 4 had similar relative frequencies.

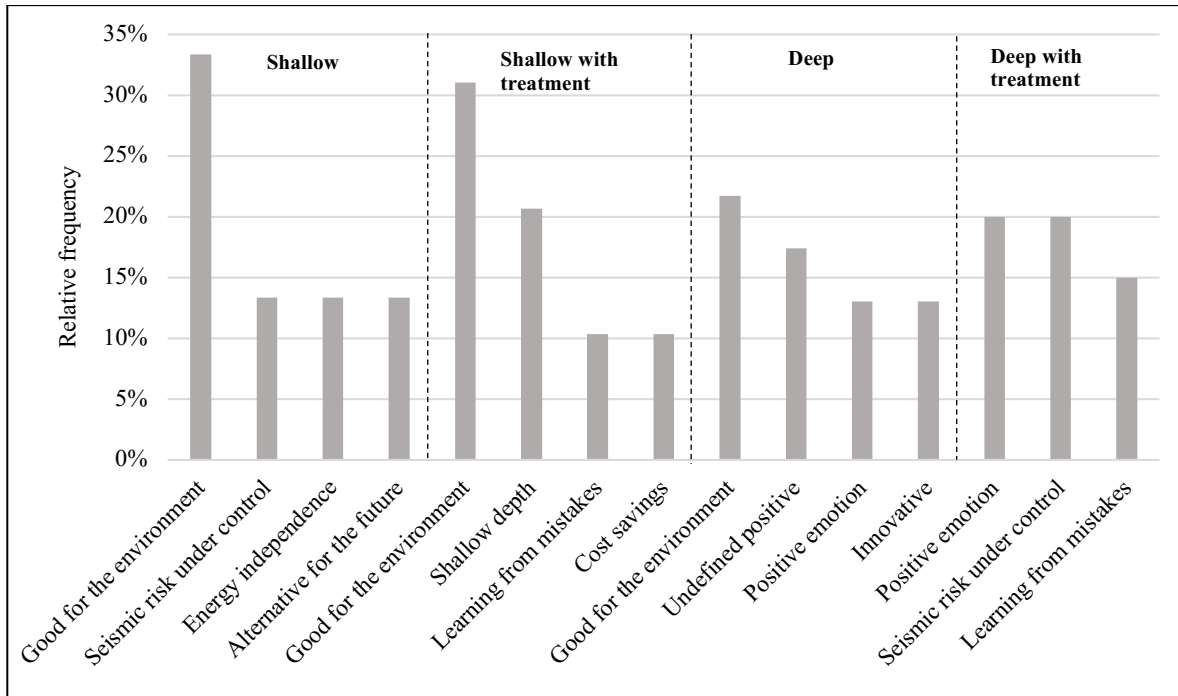


Figure 9: Thoughts elicited in favor of the geothermal projects by individuals who had initial negative affect about geothermal energy

5. Discussion

As many countries are reconsidering their energy strategies with an emphasis on renewable technologies, public acceptance of renewable energy technologies is critical to the success or failure of the envisioned energy transition. This is especially true in the case of deep geothermal projects because of their seismicity risk and associated public concerns (Stauffacher et al., 2015; Wallquist and Holenstein, 2015). Further, acceptance-related issues may also arise in the case of shallow or medium-depth geothermal projects due to the spillover effect of seismic risk related to deep geothermal projects (Dubois et al., 2019). To the best of our knowledge, no representative, large-scale studies have been conducted that provide detailed insights into and compare the effect of seismic risk on affect, emotions, attitudes, and the perceived risks and benefits of shallow and deep geothermal projects.

5.1 Affect about geothermal energy and the role of seismic risk

In general, the results reveal that information about seismic risk has a large effect on the perceptions of deep geothermal projects, but that spillover effects on perceptions of shallow geothermal projects also exist. Further, our results indicate that, in some instances, general information about geothermal energy makes individuals feel more positive about a technology. The information deficit model, which posits that if laypeople were more knowledgeable, their perceptions and judgements would be more aligned with those of experts, has been criticized for not recognizing that knowledge is only one factor among many others which are likely to guide how individuals make decisions (e.g., Bubela et al., 2009; Wolsink, 2018). While providing more information may not necessarily lead to a more positive attitude towards a project (Chavot et al., 2016); honest and transparent communication of the risks has been shown to be crucial for the success a project (Ejderyan et al, 2019).

Interestingly also, people who assessed their knowledge about geothermal energy to be low, were more receptive to provided information (i.e., had a more positive shift) than individuals who evaluated their knowledge to be high. This is important, as past studies have shown that communication may be most effective if disseminated prior to people forming strong feelings about a topic, especially if the latter are based on little to no factual knowledge (Bruine de Bruin and Wong-Parodi, 2014).

As it appears that individuals can become significantly more positive about the technology, even after being informed about the risks, project developers should be transparent about the pros and cons of projects and their potential impacts projects in all developmental stages. If they are not, in the event of controversy, criticism may focus on points that were not explained during the communication campaigns and their credibility may be undermined, as a result (Chavot et al., 2019). Importantly, however, project developers should not only opt for one-way communication but implement two-way engagement activities (Trutnevyte and Wiemer, 2017), enabling the population to become involved in the risk governance process rather than just being recipients of information.

5.2 Affect and emotions reveal a spillover effect of awareness about seismic risk on perceptions of shallow geothermal projects

The results show that it is not only being informed about seismic risk that matters, but as well how. Specifically, while the present research revealed a spillover effect of seismic risk on emotions in both Study 1 (neutral information about seismic risk) and Study 2 (more negative, emotionally laden information about seismic risk), only in Study 2, we observed a spillover effect of seismic risk information on affect. That is, in Study 2, participants who were informed about the seismic risks of deep geothermal projects were also more likely to report lower positive affect towards shallow geothermal projects compared to those not receiving seismic risk information. Most importantly, we found that the spillover effect was revealed through the affect and emotions elicited, not through attitudes. These results imply that measuring affect and emotion in addition to attitudes may produce more in-depth insights into individuals' complex affective decision-making processes regarding energy technologies. While the spillover effect of seismic risk on perceptions of *shallow* geothermal projects may not have been explicitly recognized by respondents, the effect was revealed through their reported affect and emotions. These findings generally support the call to consider both affective and cognitive factors when studying the public acceptance of energy technologies (e.g., Huijts and Van Wee, 2015; Emmerich et al., 2020; Russell and Firestone, 2021). In addition, the results highlight the need for energy project developers to take affect and emotions into account. Through a better understanding of how people feel about a project as well as of the underlying factors of their affective reactions, project developers may be better equipped to communicate with the population. Even though, from an overall perspective, the aim is to measure active support of, or opposition to a project, once this materializes, it is generally too late to intervene. Investigating affect and emotions as potential antecedents to opposition, gives project developers a chance to shape social acceptance processes as they unravel.

5.3 Perceived risks and benefits of geothermal energy and the implicit impact of seismic risk

The results further highlight that seismic risk can have a wide range of effects on the perceived risks and benefits of geothermal projects. They also show that a spillover effect of awareness about seismic risk on the perceived risks and benefits of *shallow* geothermal projects may occur. This is revealed by the fact that being informed about seismic risk decreases the perceived benefit of *shallow* geothermal projects in terms of energy independence or phasing out fossil fuels (not related to provided information about seismic risk) and increases the perception that the technology is not mature enough (related to provided information about seismic risk). These results show that even when information about seismic risk clearly indicates that the risk is related to deep geothermal projects, individuals may still associate seismic risk with *shallow* geothermal projects. As being informed about seismic risk has broad effects on its perceived benefits, policymakers or project developers seeking to promote *deep* geothermal projects should stress the benefits of the technology in communication strategies, while being transparent about seismic risk. On the other hand, when they would like to promote *shallow* geothermal projects, they should emphasize the difference in terms of seismic risk between *shallow* versus *deep* geothermal projects.

5.4 Limitations and future research

We would like to highlight five limitations of this research that may be the starting point for future work. First, while the aim of the current study was to compare how information about seismic risk presented in a more negative, emotionally laden manner as opposed to a more neutral manner² could influence perceptions, future studies may want to investigate what specific consequences or terms related to seismic risk individuals react to. Second, while the results of this study can help guide policymakers and project developers in communicating with the Swiss population, in general, reactions from the population are highly context-dependent (e.g., Ejderyan et al., 2019). Future research may thus investigate how the latter

² The terminologies *neutral* and *negative, emotionally laden* need to be interpreted in the context of this research where two types of information provision were compared. The *neutral* information in Study 1 was used as a baseline.

varies based on individual differences and project-specific characteristics. Specific factors may encompass, values, distributional justice, procedural justice and trust in the actors involved (Huijts et al., 2012; Perlaviciute and Steg, 2014; Walker and Baxter, 2017; Perlaviciute et al., 2018; Liu et al., 2019). Fourth, our measurements of affect before and after information provision were based on different techniques (i.e., general affect revealed by the affective imagery technique and reported affect toward a specific project) which should be considered when interpreting affect differences pre-post information. Finally, as the risk of earthquakes is currently inherent to deep geothermal energy projects, future research may also explore how individuals react to risk mitigation measures.

6. Conclusion and policy implications

This study investigates the effect of information about seismic risk on affect, emotions, attitudes, and perceived risks and benefits of *shallow* and *deep* geothermal projects. Additionally, it explores how presenting information about seismic risk in a neutral versus more negative and emotionally laden manner may influence the above-mentioned outcomes. Our findings have important implications for policymakers, project developers, and future research. While the results highlight that the Swiss public is generally positive about shallow and deep geothermal projects, policymakers and project developers should communicate with the population about geothermal energy before individuals form strong feelings about the technology. Our results indicate that information, even if presented negatively (e.g., the consequences of seismic risk in terms of costs and injuries), may positively influence affect towards geothermal energy for individuals whose initial affect was negative (i.e., pre-information). This is especially the case for those who appraise their knowledge about geothermal energy as poor. Early communication may help increase acceptance and prevent the decrease in acceptance that we witness in the case of wind energy (Hofer, 2020), where polarization of opinions exists, hindering constructive communication between stakeholders (Devine-Wright, 2007).

Second, the results of this research highlight the importance of measuring emotions and affect to better understand individuals' complex decision-making process regarding energy technologies and the role of affect and emotion in this process. When only measuring self-

reported attitudes, researchers may miss important insights, such as the effect of seismic risk on the affect, emotions, and perceived risks and benefits elicited by both deep and shallow geothermal projects.

Third, project developers and policymakers should stress the benefits of geothermal energy in terms of energy independence and contributing to the phasing out of fossil fuels or nuclear energy, as the value of these benefits decreases as individuals learn about seismic risk and its consequences. Also it is important that developers of shallow geothermal projects emphasize at which depth they will need to be drilling for their respective projects, as shallow depth appears to be a key element in making people feel more positive about such projects.

Further, the study highlights that making information about seismic risk more negative – such as depicted in the media, or by oppositional party-driven movements³ – indeed has a negative impact on perceptions of the technology and may lead to spillover of seismic risk perception from deep geothermal to less risky shallow geothermal projects. Policymakers and project developers should pay close attention to how the media depicts the technology to address early any fears and concerns that may arise (see Stauffacher et al., 2015). Methods for promoting effective communication and understanding among the population, project developers and policymakers, such as outlined in this research, appear as key elements of success.

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³ See for example: <http://crjsuisse.ch>; <https://www.swissinfo.ch/fre/en-suisse--la-géothermie-nage-en-eaux-troubles/45922838>

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Appendix

Appendix A: Survey Flows

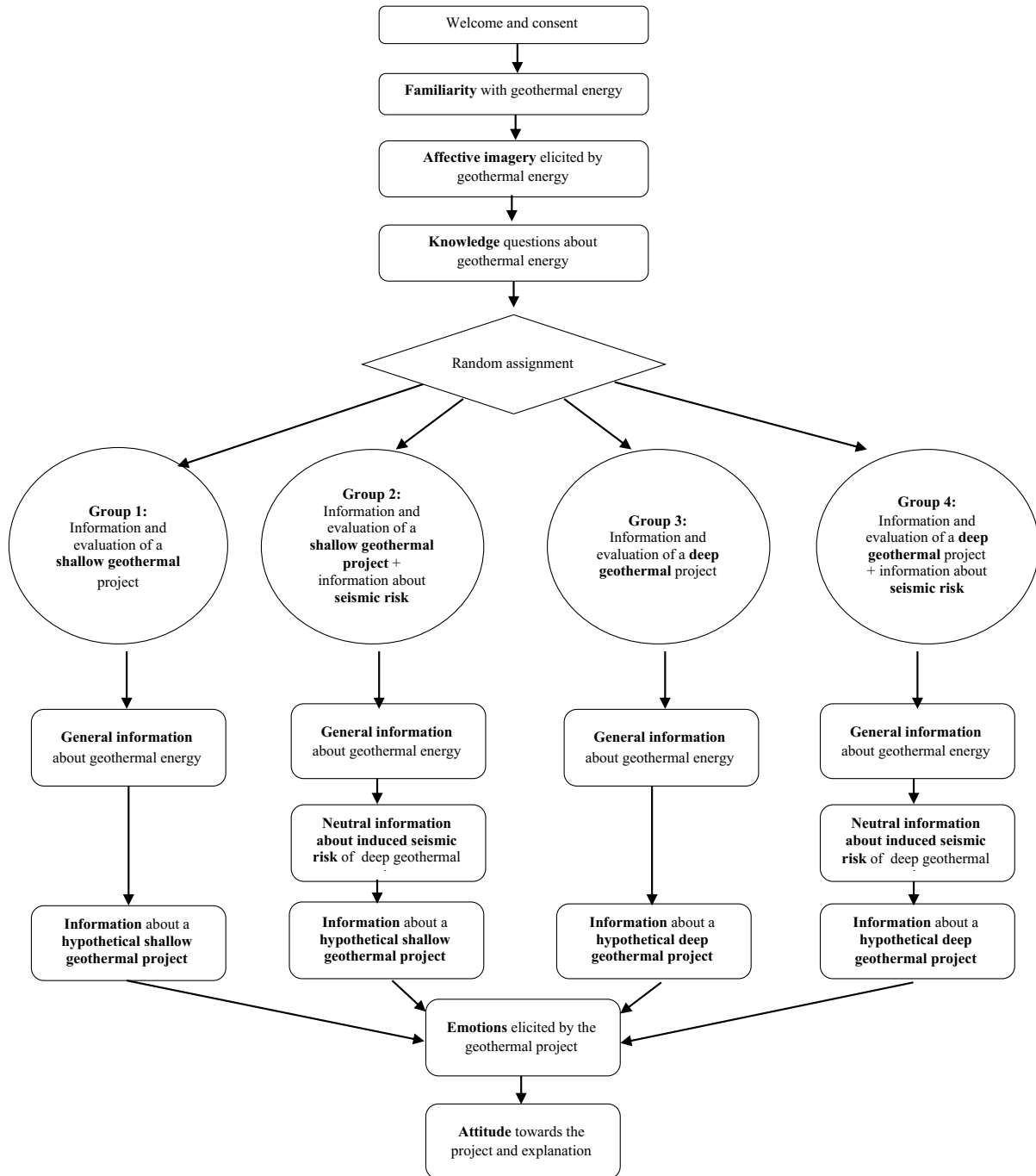


Figure A.1: Survey flow of Study 1

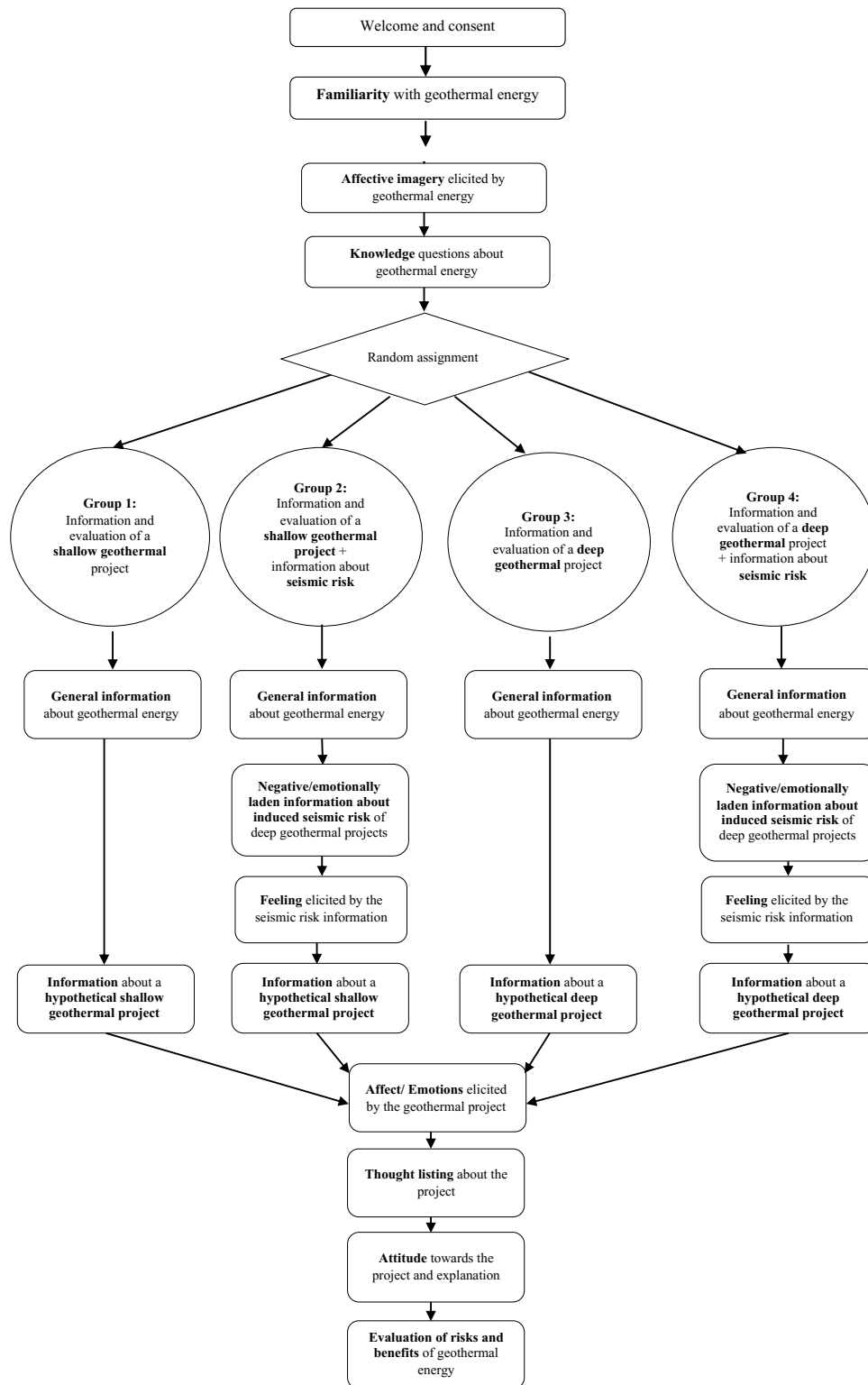


Figure A.2: Survey flow of Study 2.

Appendix B : Sample characteristics

	Shallow	Shallow with seismic risk information	Deep	Deep with seismic risk information		
Variable	Mean			p-value		Total
Gender	0.49	0.49	0.53	0.5	0.809	0.5
Regions	2.53	2.62	2.32	2.36	0.561	2.45
Age in years	46.06	46.79	46.42	44.94	0.629	46.06
Education level	0.34	0.4	0.36	0.36	0.55	0.36
Political orientation	1.649	1.93	2.22	1.734	0.262	2.05
N	252	252	260	254		1018

Table B.1 : Study 1 - Summary of statistics of sample characteristics

	Shallow	Shallow with seismic risk information	Deep	Deep with seismic risk information		
Variable	Mean			p-value		Total
Gender	0.49	0.48	0.5	0.49	0.973	0.49
Regions	2.67	2.5	2.57	2.53	0,4	2.57
Age in years	45.95	46.54	43.58	44.85	0.19	45.24
Education level	1.52	1.52	1.57	1.53	0.56	1.54
Political orientation	1.79	1.6	1.64	1.74	0.03*	1.69
N	250	253	247	257		1007

*Note : Political orientation is significantly different between group 1 and group 2 at the 0.034 significance level.

Table B.2: Study 2 - Summary of statistics of sample characteristics

Variable	Sample 1 (n=1'018)	Sample 2 (n=1'007)	Swiss adult population
Age			
Below 29	23%	22%	18%
30-44	23%	25%	26%
45-59	27%	26%	28%
60+	27%	26%	28%
Gender			
♂	50%	51%	49%
♀	50%	49%	51%
Region (excl. Ticino)			
Western Switzerland (French-speaking)	26%	25%	25%
Alps & Prealps	25%	24%	24%
Swiss Plateau West	21%	21%	22%
Swiss Plateau East	29%	30%	29%
Political orientation			
Swiss People's Party (SVP)	29%	29%	29%
The Liberals (FDP)	17%	21%	16%
Conservative Democratic Party (BDP)	4%	4%	4%
Green Liberal Party (GLP)	6%	11%	5%
Christian Democratic People's Party (CVP)	12%	8%	12%
Green Party (GPS)	7%	5%	7%
Social Democratic Party (SP)	19%	23%	19%
Others	6%		8%

Note: In study 2, the 8% from "others" have been split up between the different political parties.

Table B.3. Overall sample distribution compared to the Swiss population

Appendix C: Disclaimer

Final information on the study:

This research examines the factors that determine attitudes towards geothermal energy. The information has been adapted to answer the research questions and therefore, may not necessarily reflect the latest scientific facts about geothermal energy.

In general, experts estimate that earthquakes' magnitude greater than 5 have up to a 2-3% probability of occurring during the installation and operation of geothermal plants. The risk of earthquakes depends on a variety of factors, including high-pressure water injections during drilling. The pressure used in South Korea, for example, was much higher than that allowed in Switzerland. It is also important to differentiate between different types of geothermal energy. For example, in the canton of Geneva, les Services Industriels Genevois (SIG) plan to go down to 650 m to collect hot water at 25-35 degrees (shallow to medium depth geothermal). As for the Swiss Geo-Energy project in Haute-Sorne, its ambition is to bring hot water and electricity collected at the surface by digging 4'000 or 5'000 m deep (deep geothermal energy). All these projects are motivated by the same ambition, namely replacing fossil fuels with renewable energy sources, as stated in the Energy Strategy 2050 adopted by the people in May 2017.

Figure C: Disclaimer provided to respondents of Survey 2 who were informed about seismic risk of deep geothermal projects

Appendix D: Testing the valence of the information provided

We tested the valence of the information provided in two ways. First, we explored how the affect elicited by the geothermal project varied between Study 1 and Study 2, namely depending on if information about seismic risk related to deep geothermal projects was framed neutrally or negatively using independent t-tests. We find that respondents who received information about seismic risk in a *negative* framing (Study 2), have an elicited affect which is, on average, more negative than those who received this information in a *neutral* framing. (See Table D.1). Second, we measured the valence of the information about seismic risk provided in Study 2, by asking “How would you evaluate the text you have just read?”. The scale ranged from “very negative” to “very positive” on a 7-point scale. The results show that respondents evaluated it to be rather negative $M=3.45$ (see Table D.2).

	Neutral framing (Study 1)			Negative framing (Study 2)			p-value
	Mean	S.D.	N	Mean	S.D.	N	
Shallow	5.53	1.53	252	5.62	1.32	253	0.49
Shallow with treatment	5.35	1.56	252	4.88	1.63	250	0.00
Deep	5.55	1.48	260	5.35	1.47	247	0.13
Deep with treatment	4.85	1.68	254	4.21	1.56	257	0.00

Table D.1 : Differences in affect elicited by the geothermal project between neutral and negative framing of seismic risk

	Group	N	Mean	S.D.
Valence	Shallow with treatment	250	3.48	1.64
	Deep with treatment	257	3.41	1.68
	Average		3.45	

Table D.2 : Valence elicited by the information about seismic risk in Study 2

Appendix E: Evaluation of perceived risks and benefits of geothermal energy

#	Statements
1	I would be worried about the potential seismic risks associated with the project.
2	I think this technology is not mature enough. We need to do more research before we deploy it.
3	I think the deployment of geothermal energy is too expensive.
4	I think my region is more prone to earthquakes than other parts of Switzerland.
5	The idea of drilling in the ground worries me.
6	I would be enthusiastic about this project because it can increase our country's energy independence.
7	I would be worried about possible groundwater contamination related to this project.
8	I would be enthusiastic about this project because it can help us replace fossil fuels.
9	I would be enthusiastic about this project because it can help us replace nuclear power.
10	I believe that such a project can lead to a decrease in property values around the geothermal plant.
11	There are better alternatives such as solar energy.
12	There are better alternatives such as wind energy.

Table E.1: Statements about geothermal energy evaluated by respondents of Study 2

Categories	Shallow		Shallow with seismic risk information		Deep		Deep with seismic risk information	
	r.f.	n	r.f.	n	r.f.	n	r.f.	n
Good for the environment	33%	5	31%	9	22%	5	5%	1
Positive emotion	7%	1			13%	3	20%	4
Seismic risk under control	13%	2					20%	4
Learning from mistakes			10%	3	4%	1	15%	3
Energy independence	13%	2			4%	1	5%	1
Shallow depth			21%	6				
Alternative for the future	13%	2	7%	2				
Innovative	7%	1			13%	3		
Cost			10%	3	4%	1	5%	1
Power production			3%	1	4%	1	10%	2
Undefined positive					17%	4		
Always available	7%	1	3%	1			5%	1
Access to information/open discussion					9%	2		
Better than nuclear	7%	1						
Potential in Switzerland							5%	1
Compensation for residents							5%	1
Costs savings							5%	1
Do not live in a region prone to earthquakes					4%	1		
Inhabited area					4%	1		
Efficiency			3%	1				
New energy sources needed			3%	1				
Technology is not mature			3%	1				
Divestment from fossil fuel			3%	1				

Table E.2 : Output of the thought-listing procedure

	Category name	Example of thought:¹
1	Good for the environment	“Sustainable heat production”
2	Positive emotion	“Happy”
3	Seismic risk under control	“If enough studies have been done to guarantee a low risk of earthquakes, ok.”
4	Learning from mistakes	“Research, technology and experiments will take us further.”
5	Energy independence	“Independence of electricity and heat supply”
6	Shallow depth	“The fact that this is a shallow project will lead to no earthquake risk”
7	Alternative for the future	“In the current situation, we should explore all possibilities that contribute to improving our global climate.”
8	Innovative	“Innovative and groundbreaking project”
9	Cost	“I would be against the project if it would increase my electricity bill.”
10	Power production	“Electricity generated”
11	Undefined positive	“Better”
12	Always available	“Reliability”
13	Access to information/open discussion	“Not informed enough”
14	Better than nuclear	“X times more conceivable than nuclear energy”
15	Potential in Switzerland	“Is it really worth it in Switzerland?”
16	Compensation for residents	“Compensation needed for residents”
17	Cost savings	“Cheaper energy”
18	Do not live in a region prone to earthquakes	“Not in earthquake-critical zone”
19	Inhabited area	“Trials are best conducted in inhabited areas.”
20	Efficiency	“The functionality and mode of operation, the efficiency and effectiveness are impressive.”
21	New energy sources needed	“We need new sources of energy.”
22	Technology is not mature	“The projects are not yet mature enough to carry out safe drilling”
23	Divestment from fossil fuel	“A good alternative to fossil fuels”

Table E.3 Definition of the categories

¹ These thoughts were translated from German or French to English.

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PUBLICATIONS & PROJECT REPORTS

Cousse J., Wüstenhagen, R.; Schneider, N. (2020) *Mixed feelings on wind energy: Affective imagery and local concern driving social acceptance in Switzerland. ERSS, Volume 70, p. 101676*

Cousse, J. (2020) *Still in love with solar energy? Scale, emotions, and the social acceptance of renewable energy technologies*. Published in Renewable and Sustainable Energy Reviews.

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IAEE international conference. In Paris. Reported to 4.-7. July 2021 – Presentation of paper: Cousse, J. (2020): *Still in love with solar energy? Investigating the impact of scaling on affective reactions and acceptance*

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