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Analysis of Students' Attitude towards the Development of Renewable Energies and other Energy Sources – A Comparison between selected Canadian and German Universities

Analyse der Meinung von Studierenden zum Ausbau von Erneuerbaren Energien und anderen Energieträgern – ein Vergleich zwischen ausgewählten kanadischen und deutschen Universitäten

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Abstract

Generating energy from renewable sources can help to reduce greenhouse gas emissions from energy systems worldwide in order to meet climate targets. However, societal acceptance of green energy sources is a key factor for the implementation of further renewable projects. The focus of this thesis lies on the acceptance shown by a specific part of society, particularly students. As they are a relevant part of the energy-consuming population and can shape the energy system in their private and future professional life, their views must be disclosed to be able to give recommendations on energy development to responsible decision makers and add to the knowledge base about the support for different sources among this part of the population. Therefore, an online-survey with 1,547 university students in the cities Edmonton and Calgary in the Canadian province Alberta, and the city Munich in Germany was conducted. Based on the findings of student surveys in other countries, the examination of the survey results tests the assumptions that firstly, the majority of students would support the development of renewable energies, and secondly, that differences in viewpoints could be found between Munich and Alberta due to different geographical contexts.

The results show that in fact, most surveyed students in both countries are supportive of the development of renewable energy sources, especially solar and wind power. Less support is voiced for non-renewable sources. However, the results differ widely in this regard between Munich and Albertan students. The expansion of nuclear power, natural gas and oil is not supported by most Munich students. In contrast to that, the opinions of Albertan students disperse regarding these energy sources - there are more respondents who are in favour of further development of nuclear power, natural gas and oil. Finally, the majority of students in Munich and Alberta are against coal development. This thesis provides possible explanations and interpretations of these findings, based on information about natural, economic, and political differences between the regions as well as further survey results like the measured climate change awareness and political views of the students. The analysed data discloses students' standpoints towards the development of different energy sources and provides a starting point for scientists worldwide to expand the research in this field as well as for energy-policy making. There is great potential for a future in-depth analysis of the relation between students' support for energy sources and additional variables measured in the survey. Such investigations can build on the findings presented in this thesis.

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1. Introduction

The combustion of fossil fuels constitutes the largest share of greenhouse gases (GHG) being emitted by human activities worldwide (IPCC 2012, 7). In order to lower emissions from the energy sector, energy generation from renewable energies (RE) can play a key role. In this thesis, RE sources are defined as energy sources that occur naturally and can be replenished or renewed within the human lifespan, including flowing water, wind, heat from the earth, sunlight, and biomass (Energy Communications 2019, 62). These sources emit no or only little GHGs in the energy generation process. Thus, the implementation and expansion of RE has the potential to mitigate climate change by reducing emissions and furthermore decrease negative environmental impacts of energy generation, improve health standards, facilitate access to energy and foster economic as well as social development (IPCC 2012, 7). Yet, as of today, more than three quarters of the global energy demand are being covered by fossil fuels, while the share of RE is only 18 % (BGR 2019, 5). Thus, this fossil-fuel-based energy system must undergo a deep transformation (IREA 2018, 3). There are several barriers hindering this change. One essential barrier is the public perception of energy technologies, which is connected to societal and personal values. The further integration of RE in fact depends on social acceptance for the technology (IPCC 2012, 24f, 105; NEB 2018a, 69; Ribeiro et al. 2018, 1) because RE projects may be cancelled when facing public resistance (Kunze et al. 2017, 175). Thus, public opinion and social acceptance studies are needed to gain knowledge on people's standpoints regarding the development of energy sources, in hopes of developing strategies and policies that can encourage RE transitions.

One relevant part of the energy consuming population consists of university students. It's especially interesting to focus on them as their viewpoints and behaviour will affect how future energy markets will evolve (Qu et al. 2011). By making energy-related decisions in their every-day life, for example regarding energy consumption at home, or even when voting for a specific party during elections, they are shaping the energy system. They will do so even more in the future - may it be by settling down in a house, choosing an electricity and energy supplier, or driving energy-related changes in their workplace, if employed in the energy sector or related industries. Their viewpoints can be an important guideline for decision makers in this industry as well as policy. As previous studies have identified a relation between the perception of energy sources and the factors age and education (Engelken et al. 2016; Ribeiro et al. 2018), it's especially informative to focus on post-secondary students, who are at an exceptional stage regarding these factors, having finished secondary education and undergoing their academic career. Some studies have investigated university students' standpoints towards energy sources, especially RE (Babula et al. 2016; Gossling et al. 2005; Ozil et al. 2008; Yazdanpanah et al. 2015) but the knowledge base is still limited to few samples from selected countries. Therefore, this research aims to add to the knowledge base of students' standpoints towards the development of different energy sources which may be used by researchers in this field worldwide.

This thesis draws upon the findings of a survey conducted with students in Edmonton and Calgary, Canada, and Munich, Germany. These focus regions were selected as this thesis is a contribution to the Albertan-Bavarian Research Network for Sustainable Energy Transitions (ABBY-Net). This is a cooperation network of Bavarian and Albertan universities that has been investigating opportunities and strategies for a green energy development in both regions and hosting summer schools to train students since 2012 (ABBY-net n.d.). The survey examines students' opinions on energy production and development in Alberta and respectively Germany. This scope was set to Alberta *as a Canadian province* and Germany *as a country* because the energy situation in Alberta is special in the Canadian context (see chapter 2.1) and should be investigated on the provincial level, whereas the energy situation does not differ as much between the smaller German states, which is why the focus should be on the country as a whole. The comparison of the two areas is highly interesting because of the different socio-demographic, economic and geographical contexts. Alberta has twice the land area of Germany but 20 times less inhabitants (Statistics Canada 2016, 2019e; Statistisches Bundesamt 2019a, 2019b). Oil and gas resources are abundant in Alberta and can easily cover the provincial demand, whereas Germany's oil and gas supply is comparatively small and the country has to import the majority of its energy (CER 2019; IAEA 2019). The main differences of the energy systems will be described in detail in chapter 2, followed by an outline of the used methods for the survey conduction in chapter 3. In chapter 4, the results of students' views on different energy sources will be presented and discussed. Finally, chapter 5 gives a conclusion.

As academic literature shows that students generally have a highly positive attitude towards RE development (Gossling et al. 2005, 75; Karasmanaki et al. 2019, 111; Qu et al. 2011, 3649), the first hypothesis proposed in this thesis is that this also holds true for the surveyed students in Alberta and Germany. Additionally, this thesis aims to find out whether there are discrepancies in opinions towards other energy sources between Albertan and Munich students. This assumption is based on the finding that perceptions of energy technologies disperse out of different cultural, demographic and locational reasons (Ribeiro et al. 2018, 697). Thus, the thesis hypothesizes that there are different opinions on energy sources between the two regions due to cultural-geographical differences.

The presented findings can be used as a foundation and baseline to compare and extend the research on students' opinions about energy sources to other universities and countries. The information can be used for curriculum development, energy policy making and other developing activities regarding energy sources.

2. Overview of the Energy Context in Alberta and Germany

This chapter will present the main highlights regarding natural supply, energy generation and governmental plans targeting the energy sector in Alberta and Germany. Beforehand, the term "reserve" shall be defined as it will be used various times to describe the natural supply of sources. A reserve is a quantity of a resource that can be produced by drilling and sampling, mostly measured in tons of a certain material. It refers to the amount that is technologically and economically recoverable. This definition must be differentiated from the term "resource" as this term includes all identified material of a source - encompassing parts that may not be economically recoverable. Resources that are not yet reserves can potentially be turned into reserves by technological improvements or economic changes (Meinert et al. 2016, 3f.).

2.1 Natural Supply and Energy Production in Alberta

Alberta is a province especially rich in energy reserves, with large oil and gas supplies. The third largest crude oil reserves worldwide can be found here (Government of Alberta 2019i), with about 10 % of the global 234 billion tons of reserve. Canada holds the fourth place both in production and export of oil worldwide. 81.8 % of the oil is being produced in Alberta, mainly in the oil sands regions in the north (CER 2019). The province has the largest oil refining capacity in Canada (NRC 2019a). Furthermore, there is abundant supply of natural gas as Alberta has one of the largest reserves globally. In 2018, 69 % of marketable natural gas produced in Canada, accounting for 5 % of the global production, came from Alberta (NRC 2019c). It is therefore logical that energy development makes up the major part of the province's gross domestic product, investment and exports (Government of Alberta 2019i).

Besides oil and gas, an examination of the fuel mix for electricity generation in Figure 1 shows that further energy sources are important in Alberta. In 2018, most of the electricity came from coal combustion, as the province also commands large coal resources (see Chapter 4.3.9), followed by natural gas combustion. A small share of about 10 % was generated from RE, with wind power accounting for the majority.

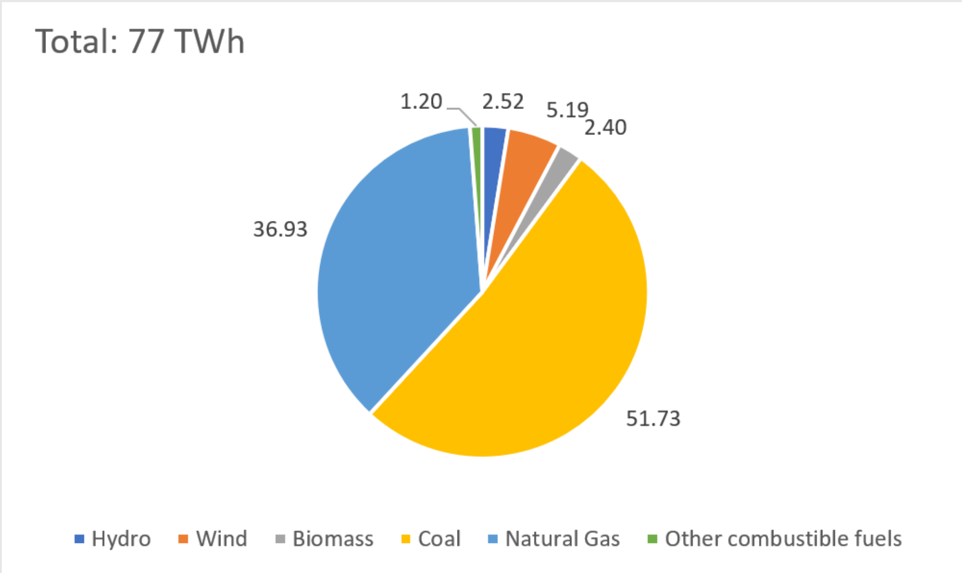

Figure 1: Electricity Generation in Alberta in 2018 by Energy Source [%] (Energy Communications 2019, 62; Statistics Canada 2019b, 2019c)

2.2 Governmental Regulations and Plans in Alberta

Several political approaches and strategies targeting the energy sector shall be highlighted. In Alberta, the production of energy is a key economic driver, with the oil and gas sector being a significant employer. Alberta had been governed by a conservative government for 44 years until 2015, when the centre-left New Democratic Party (NDP) surprisingly won the provincial elections and committed to an ambitious climate strategy. Integral components were the phase-out of coal power by 2030 and the implementation of a carbon price (International Institute for Sustainable Development 2018, IV). Moreover, the NDP Government strived to expand RE by implementing their Renewable Electricity Program (REP). In May 2019, the United Conservative Party (UCP) won the provincial election. The UCP immediately cancelled the REP and the carbon tax, calling these programs “failed ideological experiments [which] hurt […] ordinary Albertans” (JWN Energy 2019). The most important Albertan energy regulations are described below.

<u>Coal phase-out:</u> In November 2015, the NDP announced their plan to end coal-fired electricity generation by 2030. Two thirds of generation capacity were to be replaced with RE, being promoted by incentives, and the rest with natural gas (CER 2016). Since 2017, transition payments are being paid to six of 18 companies who originally intended to operate their coal facilities until after 2030. A coal community transition fund was established to financially support municipalities and indigenous people affected by the coal phase-out. The phase-out plan is still included in the official governmental homepage, even after the governmental change (Government of Alberta 2019j). However, on the governmental website for coal

development, the Ministry of Energy states that "[…] the responsible development of the province's extensive coal deposits […]" is encouraged (Government of Alberta 2019a).

Renewable Electricity Program (REP): The REP was introduced in November 2016 and set the target of increasing the electricity generation from RE to 30 % until 2030 (Energy Communications 2019). Three rounds of bidding auctions for contracts were held (CBC 2019) until the new Government informed the Albertan Electric System Operator (AESO) in June 2019 that the REP would not be continued and that there would be no more competition rounds (AESO 2019). The granted projects -most of them wind turbines - add a capacity of 1,360 MW and will come online in 2019 and 2020 (Energy Communications 2019, 62). To reach 30 % renewable generation, 5,000 MW of renewable capacity would have been needed (CBC 2019).

Carbon Tax: The NDP furthermore introduced a carbon levy as a tax on transportation and heating fuels. It was in effect from January 2017 until its cancellation in May 2019 (Government of Alberta 2019e). However, a carbon tax is to be implemented federally and hence also in Alberta in 2020. The Alberta Ministry of Justice has filed an appeal against this (The Globe and Mail Alberta 2019).

Carbon Competitiveness Incentive Regulation (CCIR): In December 2017, the CCIR was implemented (ACCO 2018). It can be considered a management approach for oil sands' GHG emissions as it sets an annual limit of 100 Mt on emissions from oil sands per facility and aims to incentivise research on and development of new carbon emission reduction technologies (Energy Communications 2019, 50). Facilities that emit more must buy emission performance credits from other generators or offsets from RE projects.

2.3 Natural Supply and Energy Production in Germany

The energy situation in Germany is quite different from the one in Alberta. Germany does not command as many natural resources, especially in terms of oil and gas, and imports approximately 70 % of the consumed energy (AGEB 2019a).

The domestic production of energy has decreased by 37 % since 1990 (AGEB 2019b, 5). Figure 2 shows that the largest source for energy generation in 2018 was RE (46,1 %), followed by lignite (38,8 %).

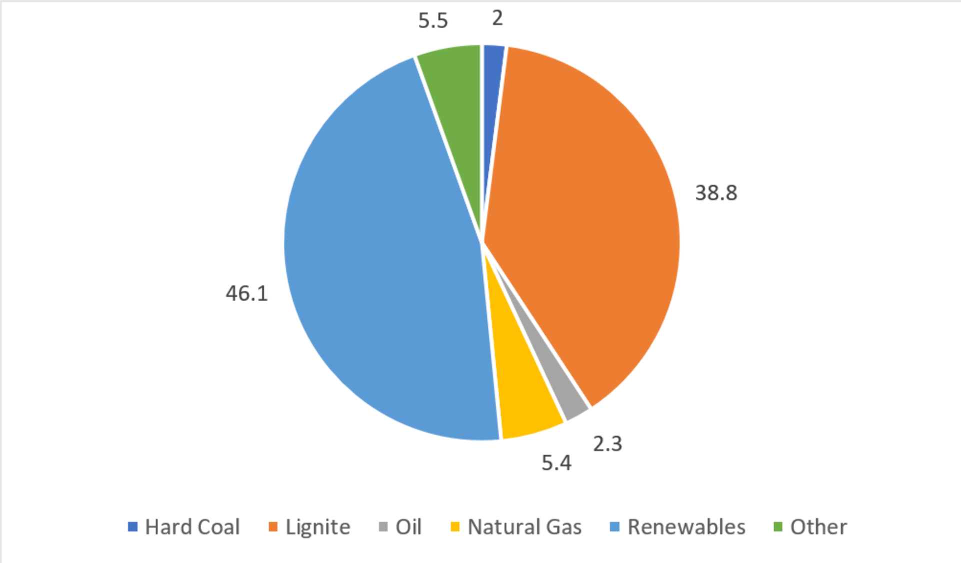

Figure 2: Domestic Energy Production in Germany by Fuel in 2018 [%] (Own Illustration based on AGEB 2019b)

However, as Germany imports the majority of the energy needed to cover the heating, cooling, fuel, and electricity demand, the imports need to be considered as well. In 2018, 42.9 % of the import was natural gas, followed by oil (39.7 %), hard coal (9.7 %) and nuclear energy (6.2 %) (AGEB 2019b). This results in 80 % of the primary energy demand being covered by fossil fuels (IAEA 2019).

Large discrepancies between Alberta and Germany can be noticed when examining the electricity generation mix. Apart from the fact that Germany produced over 8 times more electricity than Alberta in 2018, the share of RE is significantly higher (35 %), as presented in Figure 3. The remaining 65 % are supplied by a mix of different sources, including natural gas, coal, oil, and nuclear energy. The latter is not being used in Alberta at all.

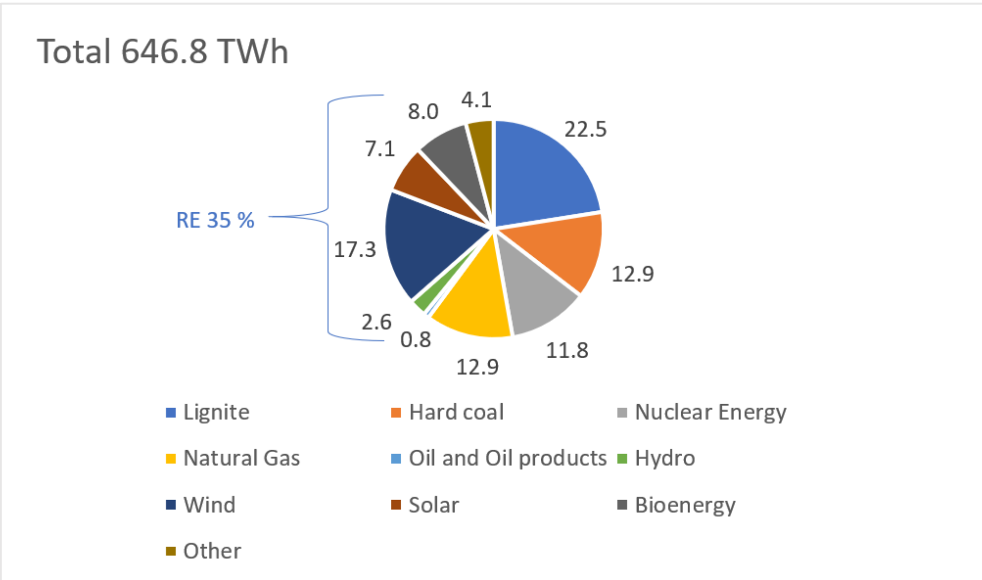

Figure 3: Electricity Production in Germany by Fuel in 2018 [%] (Own Illustration based AGEB 2019c)

2.4 Governmental Regulations and Plans in Germany

As one of the largest energy consumers globally, the German government is implementing different measures targeting the energy sector to reduce emissions and reach climate goals. The government plans to reduce the domestic primary energy demand by 20 % until 2020 and by 50 % until 2050 compared to 2008 levels (UBA 2016). Apart from energy efficiency measures, increasing the energy generation from RE is an important milestone. Key points are incorporated in the EEG, which will be outlined in the following, together with other main strategies.

The "Erneuerbare Energien Gesetz 2017" (Renewable Energies Act, EEG): Implemented in 2000, the EEG was designed to support the further development of RE technologies. The law obliges grid operators to prioritize the addition of RE facilities into the grid as well as the purchase of RE electricity. Wind turbines and photovoltaic (PV) facilities under a capacity of 750 kW and Biomass facilities under 150 kW receive a fixed feed-in compensation for 20 years. Above this threshold, the amount of the feed-in tariff is being determined via bidding auctions organised by the federal grip operator (UBA 2019b). The law's aim is to increase the share of RE electricity in the gross electricity demand to 40 to 45 % until 2025 and at least 80 % until 2050 (Bundesamt für Justiz 2019). The EEG has contributed to a significant increase in RE generation. Since 2000, the share of RE in gross electricity generation has risen from 6,6 % to 35 % in 2018, as can be seen in figure 4.

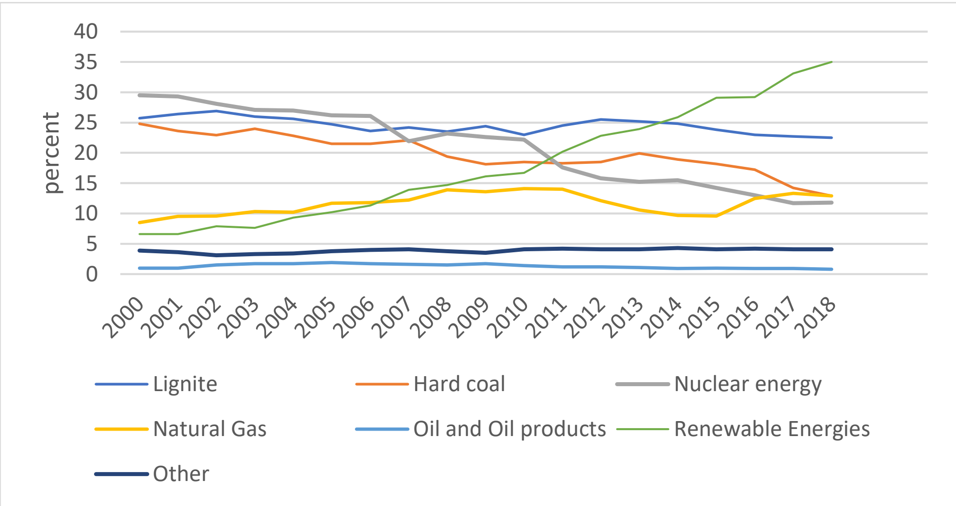

Figure 4: Share of Energy Sources for Electricity Generation in Germany (Own Illustration based on AGEB 2019b)

Coal Phase-out: Following the 2019 recommendations of the Commission on Growth, Structural Change and Employment, the government is developing a plan to end electricity production from coal combustion in Germany by 2038 (BMWI 2019c).

Nuclear phase-out: Rising public scepticism about the risks of nuclear energy motivated the governmental adoption of the Atomic Energy Act in 2002. It determined a structural phase out of atomic energy for electricity generation and a ban for any new project. After the nuclear disaster in Fukushima in 2011, the government decided to decommission all power plants with no exception until 2022 (IAEA 2019).

3. Methods

After outlining the energy contexts in the examined regions, the development, distribution, and analysis of the questionnaire will now be described. Potential biases in the data will be addressed.

3.1 Questionnaire Development

The survey was developed at the University of Alberta (UofA) in Canada in Summer 2019. The main research questions are:

- To what extent do students support or oppose the development of different energy sources in Alberta and Germany? Do opinions vary between students in Alberta and Munich?
- What is their willingness to use RE electricity at home and to invest money in a community-owned RE project?
- Are the above-mentioned standpoints related to factors like energy knowledge, climate crisis awareness, faculty, educational level, age, gender, country of origin, political views, and living situation? If yes, how?

The questionnaire consists of 44 questions, with open-ended and close-ended questions (see Appendix 1). The online survey tool Qualtrics was used for the implementation.

3.2 Distribution Methods and Sampling Size

The survey was distributed to students at the UofA, the University of Calgary (UofC) and tertiary institutions in Munich. At the UofA, the survey was promoted mainly by contacting departments and faculties who then helped to distribute the link via mailing lists, newsletters and social media groups. Additionally, flyers were handed out and posters were put up on bulletin boards around campus (see Appendix 2 and 3). 944 UofA students completed the questionnaire between September 19th and October 14th, accounting for 2.7 % of UofA students (UofA 2018). At the UofC, three professors and ABBY-net members helped to forward the link to their students. There were 72 responses from the UofC, which is about 0.2 % of all UofC students (UofC 2019). Due to more limited distribution opportunities, the sample is much smaller than the UofA sample. In total, the Albertan sample consists of 1016 students. In Munich, the survey was online from October 24th to November 15th. Awareness was raised mainly via social media groups and a survey mailing list at Ludwig-Maximilians-University (LMU). 531 students completed the survey, accounting for less than 0.5 % of all Munich students (LMU München n.d.; TUM n.d.).

3.3 Potential Biases

As this is not a probability sample, the findings cannot be generalized to the whole student body in Munich, Edmonton or Calgary. The participation in the survey was voluntary and thus, the self-response bias may be high. This means that it is likely that many of the respondents took part because they are interested in energy issues. The positions of these students may differ from other students' viewpoints and therefore skew the results, leading to an underrepresentation of students' opinions who are not as interested in energy issues. Statements can therefore only be made about the drawn sample, keeping in mind that the main limitation of this study is that the findings only apply to these respondents. Survey results also do not include individuals in trade schools or other types of post-secondary education.

3.4 Data Analysis

The collected data were analysed using the Statistical Package for the Social Sciences (SPSS). The focus of this thesis lies on the analysis of Question 5(Q5):

In general, to what extent do you support or oppose further development of the following energy sources in Alberta/*Germany*?

	Strongly Support	Support	Neutral	Oppose	Strongly Oppose	I don't know
Oil (and Oil sands*)						
Wind						
Hydro						
Geothermal						
Nuclear						
Coal						
Solar						
Biomass						
Natural Gas						

**the Munich survey did not ask for oil sand development, as Germany does not command oil sand resources.*

The presentation and interpretation of the results will give an overview over students' position towards energy sources. It is a relevant starting point for future analyses of connections between these standpoints and other variables and factors in the dataset. By examining the positions towards each energy source individually, the exact differences in students' opinions towards the development of these types can be better understood and put into context.

Apart from a descriptive report of these findings, an interpretation of students' position will be given. As societal opposition towards RE is a major barrier for RE implementation (see chapter 1), it is essential to investigate the reasons for disapproval of RE development. Therefore, the surveyed students who chose to oppose the expansion of one or more RE source received specific follow-up questions asking for the reason for their position. Likewise, students also received follow-up questions if they chose to support non-RE development, asking for the reason by giving some answer suggestions but also allowing additional text entry. Multiple answers were possible. For oil (and oil sands), the follow-up question looked like this:

Specifically, why do you support the development of oil (and oil sands)? Please choose all that apply.

- ☐ Currently inexpensive and easy to extract
- ☐ Abundant supply, especially in Alberta/*Germany*
- ☐ The oil industry provides an employment opportunity in Alberta/*Germany*
- ☐ Production (infra)structures are already established
- ☐ Reliable and capable of generating large amounts of power
- ☐ A member of my family works in this sector
- ☐ Other, please describe:

Corresponding questions and answers were designed for the other energy sources (see Appendix 1, Q5.1 – 5.9). In addition, the interpretation will draw on the most relevant findings from Spearman's correlation tests and *t*-tests for a better understanding of data patterns. *P*-values, which are defined as the probability that the result is at least as extreme as the actually observed results under a statistical model (Wasserstein et al. 2016, 131), are considered significant at a <.05 level and highly significant at a <.01 level.

Of the further measured variables in the questionnaire, the students' political views as well as their level of climate crisis awareness (CCA) will be taken into account during the interpretation for the scope of this thesis because striking correlations with these variables were identified in some cases. Political views were measured on a seven-point scale ranging from very conservative (1) to very liberal

(7), also giving an “I don’t know” and “no comment” option (see Appendix 1, Question 19). The students’ CCA was measured using a five-item scale, targeting different aspects of sustainability and climate change concerns (see Appendix 1, Questions 12.1-12.5). Questions 12.2 to 12.5 were reverse coded, and values were added up to constitute the CCA scale. The score ranges from 5 being the lowest and 25 being the highest level of CCA.

4. Results

In this chapter, the findings from the survey will be presented. Firstly, demographic features will be outlined to understand the characteristics of the samples, as well as the results for students’ CCA level. Afterwards, the results of students’ opinions on the further development of each energy source will be presented and discussed.

4.1 Overview of the main demographic Features

The majority of 28 % of UofA students surveyed are enrolled in the Faculty of Science, followed by Arts (23 %) and Engineering (11 %). 54 % of the sample are female, which is similar to the actual gender distribution at the UofA (Olfert 2019). The age ranges from 17 to 64, with 20 being the mode. 75 % of the students are between 18 and 27 years old.

The UofC sample demographics closely resemble the UofA ones regarding age and enrolment distribution across faculties. Most UofC participants come from the Science Faculty, mainly the Departments of Geoscience and Geology, followed by arts students, who mostly study Geography. There are as many male as female participants, which varies from the actual distribution of 53.4 % women at the UofC (UofC 2017).

In Munich, 64 % of the 531 participants study at the LMU, which is the University for Arts, Humanities and Natural Sciences. 33 % are doing a degree at the Technical University (TU) Munich and 3 % study at other universities. The largest cluster of students (16 %) study at the Faculty of Geosciences at the LMU. The second largest group is from the TU Science Center Weihenstephan for Nutrition, Land Use and Environment (8 %), followed by the LMU Faculty of Language and Literature studies (5 %) and the LMU Faculty of Social Sciences (5 %). A majority of 53 % of the sample are female, implying that the proportion of female participants is larger than the real proportion of female students at TU and LMU combined (49.5 %) (LMU München n.d.; TUM n.d.). The sample’s age ranges from 17 to 67. The age selected most often (14 %) is 22. 88 % of students are between 18 and 27 years old.

4.2 Results for Students' CCA Levels

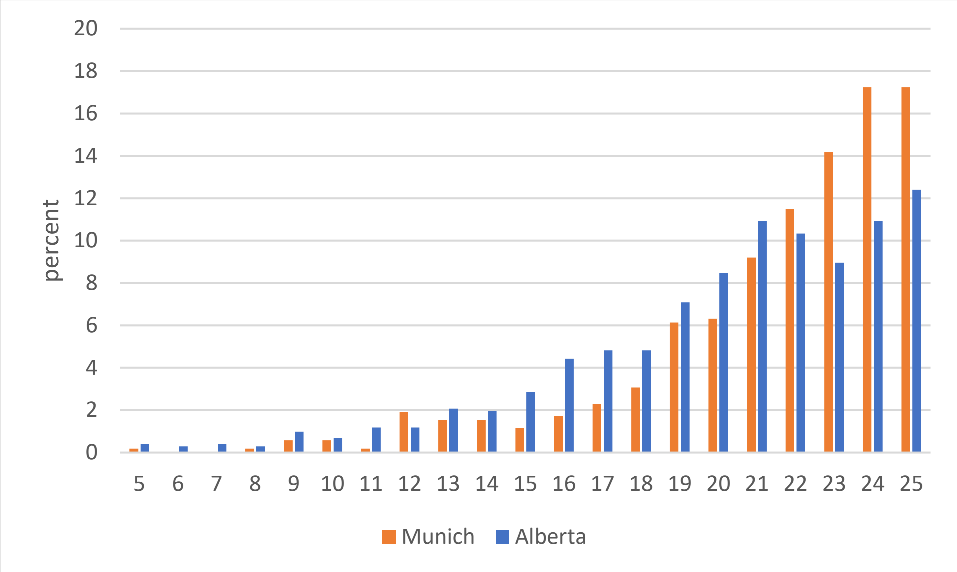

Figure 5: Results of Students' Scores on the CCA Scale (n = 516 in Munich, n= 960 in Alberta)

Figure 5 shows that 60 % of the Munich students obtain the highest score between 22 and 25 points, whereas in Alberta it is 43 % of the sample. Generally, both samples show a high CCA as only few people (8 % in Munich, 12 % in Alberta) score 15 points or less. These high levels may be a result of a social desirability effect, given the broader context of the survey focusing on energy sources and their environmental consequences. Still, the lower CCA levels among Albertan students in comparison to Munich students are identifiable by the 17 % gap in the scores between 22 and 25 points. One of the comments left by a student in the feedback field at the end of the survey explicitly refers to a personal experience regarding low CCA in Alberta:

> *"[…] People's livelihoods depend on oil and gas in this province, so many take offence to the mere suggestion of renewable sources. I attended a climate protest in a small Albertan town this last September and there were more counter protesters than there were protesters. That speaks volumes about how Albertan's feel regarding climate change."*
>
> -UofA Chemical Engineering student

Another comment speaks to the relation between the energy sector and CCA:

> *"[The biggest barrier for RE development is] people not realizing the threat of climate change from our current energy"*
>
> - UofA Computer Science student

In this context, the CCA of this Albertan student sample is comparatively high. The differences to Munich students' scores might partly be since students from other faculties responded to the survey in Munich than in Alberta. A further analysis of the sample features can possibly detect relevant associations, providing more explanations on the different CCA levels of the drawn samples.

4.3 Students' Opinions on Energy Development

Table 1 shows the results of students' opinions on the further development of different energy sources in Alberta and in Germany.

	Strongly Support	Support	Neutral	Oppose	Strongly Oppose	I don't know
Solar	69.0	23.9	4.0	1.2	0.7	1.2
	74.6	20.3	3.2	1.1	0.4	0.4
Wind	51.9	34.4	8.0	3.3	1.0	1.4
	56.7	35.0	4.0	2.3	1.7	0.4
Geothermal	42.2	36.5	10.1	1.3	0.2	9.6
	43.3	31.5	13.7	2.3	0.8	8.1
Hydropower	36.2	40.6	13.6	5.3	1.0	3.2
	55.2	33.5	5.1	4.3	1.1	0.4
Bioenergy	35.7	34.9	18.2	4.2	1.9	5.0
	20.7	34.8	21.3	11.9	1.9	9.2
Nuclear	25.2	22.2	20.2	17.3	9.2	5.9
	7.5	9.6	14.3	20.5	46.1	1.9
Natural Gas	12.3	25.1	31.9	20.2	7.1	3.4
	2.3	12.4	21.1	37.5	20.5	5.8
Oil (and Oil sands*)	10.5	22.3	19.8	25.7	20.0	1.7
	0.4	1.3	7.9	27.5	61.8	0.9
Coal	2.4	5.2	14.6	29.0	46.1	2.8
	0.2	0.8	3.6	15.4	79.3	0.4

Table 1: Responses to Q5 [%], Blue = Alberta, White = Munich (Sample sizes vary slightly depending on the source, see corresponding subchapters) (Own Illustration)
(excluded from the Munich survey)*

The first fundamental finding is that the support for RE development is extremely high among both samples. Solar energy receives the strongest support, followed by wind energy. Hydro power and geothermal energy receive a little less support but the majority of students are still in favour of further development. A significant difference ($t(1{,}495) = 10.067$, p =.000) can be found between Alberta and Munich in terms of bioenergy; 70.6 % of Albertan students support this energy source, while only 54.8

% of students in Munich want further development. This leaves biomass the least supported RE source, however most students of both samples still advocate for biomass development.

The results for non-RE sources are not as unanimous. The differences are most striking regarding oil and oil sands, nuclear and natural gas development. 32.8 % of Albertan students support the further development of oil and oil sands in Alberta, whereas only 1.7 % of students advocate this in Germany. In fact, the Munich students are clearly not supportive of oil development, with 89.3 % opposition. The situation is similar regarding nuclear development, as a majority of 66.6 % of Munich students disapprove nuclear development whereas almost half of Albertan students advocate it. Regarding natural gas, the percentage of students opposing the further development is again larger in Munich than in Alberta. The only energy source that does not receive support from a majority of 92.5 % of Albertan students and 99 % of Munich students is coal.

In the following subchapters, the students' position towards each energy source will be discussed in detail. For every source, the background regarding current development, natural resources, and economic and political context will be outlined. The subchapters are structured from the most to least supported energy source, according to the Albertan students' responses. To simplify the analysis, "neutral" and "I don't know" responses were grouped together.

4.3.1 Development of Solar Energy

Solar energy refers to the utilization of energy from the sun for electricity generation with PV cells and for heat generation (CER 2017, 20).

Context in Alberta

Alberta is located between 49 and 60 degrees latitude and is among the provinces richest in sunlight throughout Canada. This and the cold Albertan climate result in a high natural potential for solar energy generation of 1,100-1,400 kWh per kW of installed capacity annually (Solbak 2016, 6). Installed capacity refers to the amount of energy that could be potentially produced in one hour under ideal weather conditions. Alberta could produce 63 TWh per year, neglecting areas that have been identified as suitable for wind energy development (Barrington-Leigh et al. 2016, 23ff.). This relatively high potential is often compared to the solar potential in Germany as this country is perceived as one of the leaders in the solar energy technology market (Dodge et al. 2012).

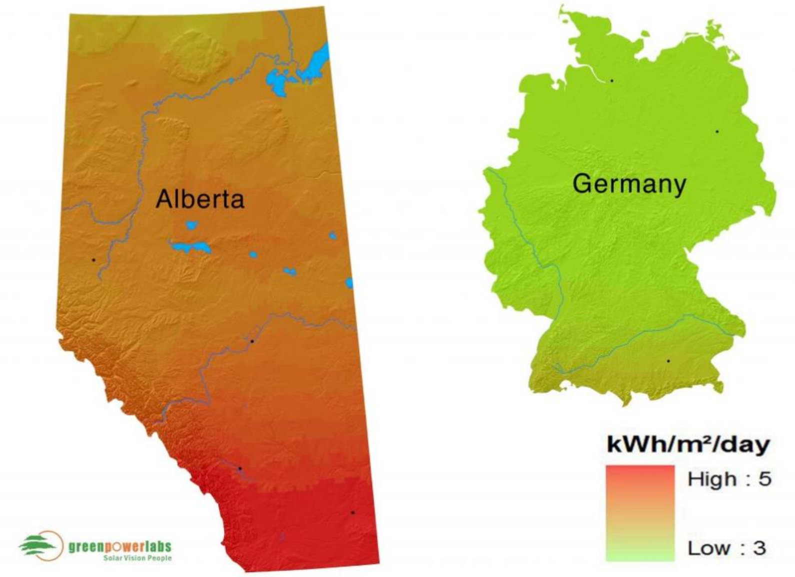

Figure 6: Maximum daily solar Resource for Alberta and Germany [kWh/m²/d] (Dodge at al. 2012)

From Figure 6, it can be deduced that Alberta has a larger daily solar resource than Germany. However, as of 2018, much less energy is generated from solar power in Alberta than in Germany. Only 25,547 MWh were generated from solar power that year, accounting for approximately 0.03 % of the electricity supply (Statistics Canada 2019a). 42.7 MW of capacity were installed as of June 2018 (Gallagher et al. 2018, 4).

Context in Germany

Germany, on the other hand, ranks 4th place in terms of installed solar capacity worldwide with 45.9 GW, representing 9 % of the global installed capacity (NRC 2019b, 102). Due to peak levels of solar irradiance in Germany in 2018 (AGEB 2019a) and a 7 % increase in installed capacity, the electricity generation from PV plants in Germany increased by 16 % from 2017 to 45,800 GWh in 2018 (AGEE 2019, 6). This represents 7.1 % of the electricity production in Germany. Figure 7 shows how solar electricity generation in Germany has increased significantly from 2000, the implementation year of the EEG, to 2018.

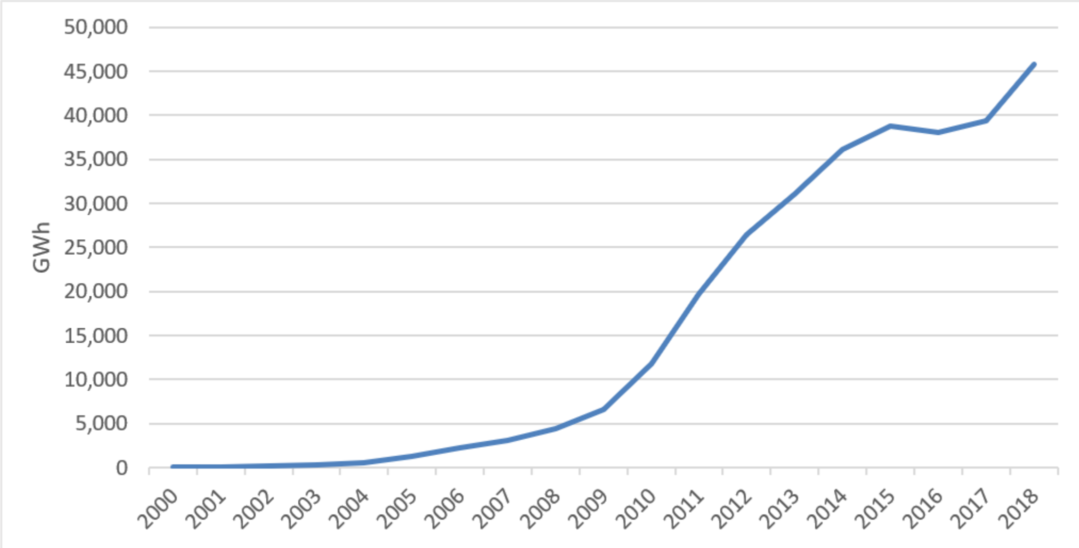

Figure 7: Electricity Production from Solar Energy in Germany (Own Illustration based on AGEE 2019)

Solar panels produced an additional 8,900 GWh of energy for heat generation in 2018 (AGEE 2019, 8).

The average annual solar irradiation in Germany is 1,055 kWh/m². Rates are highest in the south of the country in the state of Bavaria where the annual sum of irradiation can be up to 1,200 kWh/m² on a horizontal area (Energie-Atlas Bayern n.d.). This translates to an annual potential of 848 kWh/kW in Berlin whereas – for comparison – the potential is 1,245 kWh/kW in Edmonton and 1,292 kWh/kW in Calgary (Solbak 2016, 6). But even though the potential is higher in Alberta, there is still room for development in Germany. A study commissioned by the Federal Ministry of Transport and Digital Infrastructure estimates a further potential of 228 GW capacity in non-restriction open spaces. Roofs and facades offer a technical potential of at least 1.4 TW. As 1773 km² of land were destroyed by lignite mining, 55 GW could be added by flooding this area and covering it with floating solar panels (Fraunhofer ISE 2019, 37f.).

Students' Opinions on Solar Energy Development

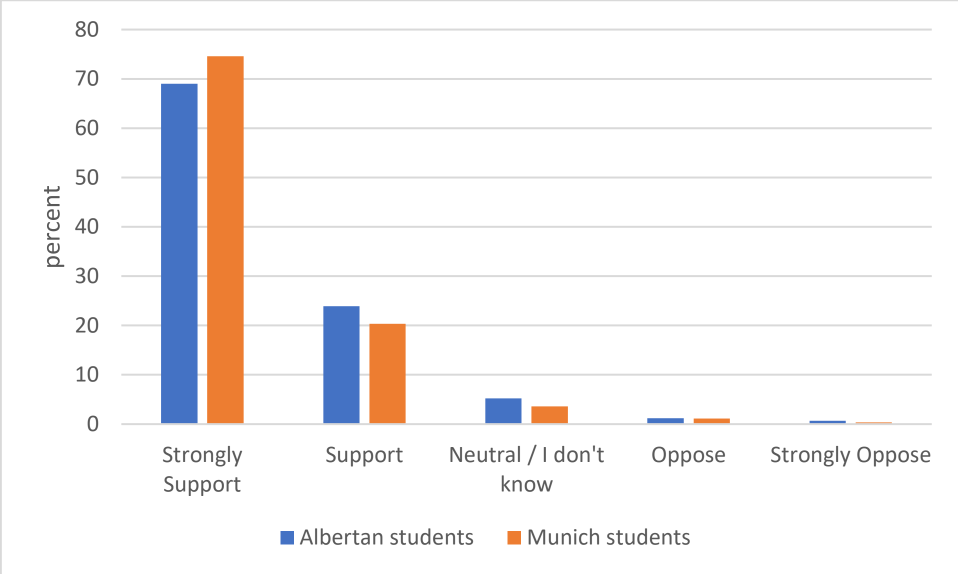

Figure 8: Results for Q5: Development of Solar Energy (Alberta n= 1004, Munich n= 529) (Own Illustration)

Students both in Alberta and Munich support solar energy development the most, compared to all other energy sources (see Figure 8). In both samples, only very few students respond neutral or undecided – 5.2 % in Alberta and 3.6 % in Munich – and even less students choose to oppose solar development – just 1.9 % in Alberta and 1.5 % in Munich.

Discussion

The high support for further solar energy development aligns with other studies' findings that students perceive solar energy most positively of all energy sources (Karasmanaki et al. 2019, 114) and consorts with findings that students are most knowledgeable about solar energy (Assali et al. 2019, 257; Karatepe et al. 2012, 117). An explanation for these outcomes may be the generally high CCA levels among the samples, as presented in chapter 4.2. There are significant correlations between the students' CCA score and their support for solar energy (r_s=.383, p<.01 in Alberta, r_s=.290, p<.01 in Munich). The high support may thus result from the perceived environmental benefits of solar as a low-carbon energy source. The absence of perceived negative aspects compared to other RE sources, presented in the next subchapters, can explain why solar is the most popular RE source. Interestingly, many Albertan students are in favour of an expansion although solar has only played a minor role in the provincial energy mix so far, even compared to other RE sources like wind and hydro. The students may be aware of the great but widely unused potential and therefore support the development. This may also be a reason for Munich students to respond supportive.

4.3.2 Development of Wind Energy

Wind energy is generated by installing turbines with blades that spin in the wind and drive a connected generator (CER 2017, 12).

Context in Alberta

Apart from having large natural solar power resources, Alberta is a province with strong and steady winds, especially in the south. Wind energy can be economically generated in over 33 % of the land area (Government of Alberta 2019c). A 2015 study identified a wind potential of 169 TWh per year in Alberta, even when only taking into account 25 % of the high wind potential area in the province due to competing land uses (Barrington-Leigh & Ouliaris 2016, 33).

Yet, in 2018, wind turbines generated only 4.1 TWh, accounting for 5 % of electricity generated in Alberta. This still makes wind the RE source that produces the largest percentage of electricity (Statistics Canada 2019a). Since the construction of the first commercial wind farm in 1993, the province established the third largest installed capacity in Canada today with 1,483 MW, representing 12 % of the total amount. Wind energy is now the most cost-competitive source for new energy in Alberta (CanWEA 2019). Under the REP, wind power projects totalling 1,300 MW capacity were approved, which will be installed and fed into the grid over the next two years. This, however, is still only "scratching the surface of the province's wind power potential" (Government of Alberta 2019c). The government officially states that the further expansion of wind energy is wanted and planned, especially in southern Alberta (Government of Alberta 2019k). But with the cancellation of the REP, the development of wind power will be much less attractive for private investors and the industry.

Context in Germany

In terms of electricity generation, wind energy also accounts for the largest share of RE sources in the electricity mix in Germany. But in contrast to Alberta, wind energy constituted as much as 17.3 % of electricity generation with 110 TWh in 2018. Only power generation from lignite took up a larger percentage. With support from the EEG, the installed capacity increased from 6,097 MW onshore and 0 MW offshore in 2000 to 52,565 MW onshore and 6,417 MW offshore in 2018 (AGEE 2019, 6). Germany thus has the third largest installed capacity of wind power worldwide, with 10 % of the global capacity (NRC 2019b). Nonetheless, studies identify a large potential for further expansion in Germany (Callies 2015, IV) as a total capacity of 200,000 MW could be installed if 2 % of the land area in every German state was utilized, resulting in an electricity generation of 390 TWh annually (BWE 2011, 5).

Students' Opinions on Wind Power Development

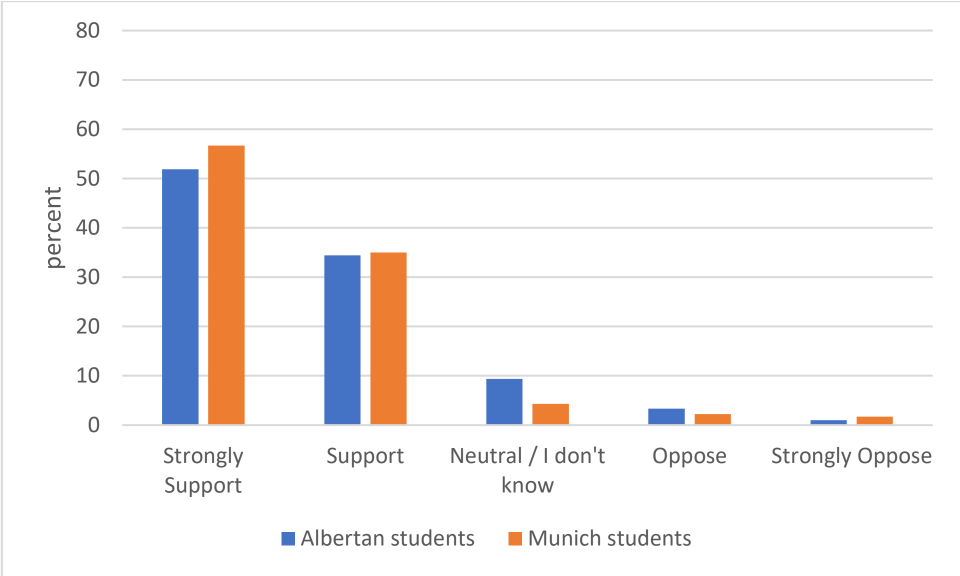

Figure 9: Results for Q5: Development of Wind Energy (Alberta n= 1002, Munich n= 529) (Own Illustration)

After solar, wind is the second most supported source. Again, students in Alberta and Munich strongly advocate wind power development with 86.3 % and respectively 91.7 % of approval (see Figure 9). More Albertan students are neutral towards the energy source (9.4 %) than German students (4.3 %). Compared to solar, opposing responses are only slightly higher.

Discussion

Again, the high support may be explained by the high CCA levels prevalent in both samples that motivate the support for this non-GHG-emitting RE source. It is positively correlated with a higher CCA (r_s=.310, p<.01 in Alberta, r_s=.308, p<.01 in Munich). Another driving reason in Alberta may be students' awareness of the great wind potential and cost competitiveness. It is striking that, in contrast to solar power, wind power is developed more in Alberta but receives a little less support from the students. Looking at the reasons why 4.3 % of Albertan students choose to oppose wind power, the option with 74 % of votes was the disruptive visual impact and extensive land use of wind turbines, followed by high initial investment and/or ongoing maintenance costs (65 %). There seems to be misinformation regarding the latter, as wind power is cost-competitive in Alberta today. Visual impacts and land use are also the reasons selected by 80 % of the few Munich students who are against wind power development. The perception of these aspects may drive some students to respond "neutral" or "I don't know" here, as their choice may conflict with their awareness of wind power benefits. In conclusion, the majority of students show a highly positive attitude towards wind development.

4.3.3 Development of Geothermal Energy

Geothermal energy is the generation of energy from the earth's heat, for example from magma, hot stones, hot water or steam. Compared to other REs, it can provide base load power, is very reliable, and has low fuel, operational, and maintenance costs (CER 2017, 25).

Context in Alberta

Geothermal energy has been developed worldwide since over 100 years. It has the potential to play an important role in Canada but has not yet been developed extensively there. All regions in Canada are suitable for geothermal energy generation but Alberta is among the five areas with the greatest potential (CER 2017, 24f) with an estimated potential energy capacity of 389 GW (Leitch et al. 2017, 3).

Existing infrastructure in Alberta is well suited to be transformed into geothermal energy generation sites. Oil and gas wells may be used for geothermal purposes, creating a synergy with the oil and gas industry's knowledge of drilling and sub-surface structures (Alleckna 2017). 60,935 of Alberta's inactive and active wells are estimated to be able to produce geothermal energy based on the temperature at the bottom of the well (Leitch et al. 2017, 6). The interest in the geothermal sector is increasing not only because of this synergy but also because of rising availability of data, technological progress and the growing need for low carbon solutions (NADC 2019, 2f). A 2018 study of 42 communities in northern Alberta found potential for geo-exchange, which is energy extraction from just a few meters below the surface, in all communities. 12 sites were even identified as suitable for power generation with temperatures above 90 degrees Celcius (NADC 2019, 5).

So far, few small scale shallow geo-exchange projects exist in Alberta but there are no large-scale commercial facilities. Policy frameworks are still under development. At the moment, projects are being reviewed case by case (NADC 2019, 3). A 6.7 million Canadian dollar geothermal engineering project west of the Albertan City of Red Deer has recently been granted funding from the Ministry of Natural Resources (Natural Resources Canada 2019). In the survey comments, a UofA Earth and Atmospheric Sciences student mentions a research opportunity that he's involved in:

> *"I do work on geothermal energy in Alberta, […] on developing an enhanced geothermal system near Fort Mac[Murray] to extract oil from oil sands. This would eliminate CO2 emissions from heating water by using earth's heat as opposed to natural gas which is currently used."*

Context in Germany

In Germany, on the other hand, geothermal energy has been used to generate heating and cooling energy since before 1990 and electricity since 2004 (AGEE 2019, 6,8). As of 2019, there are 37 deep geothermal facilities (at a depth of 400 meters or lower) operating in Germany. 33 of them can produce heat, 4 can produce electricity and 5 can produce both. The total installed capacity is 336.51 MW for heating and cooling and 37.13 MW for electricity. There are around 390,000 near-surface facilities (above 400 meters) with a 4,290 MW capacity for heat production (Bundesverband Geothermie 2019).

In 2018, a total sum of 14,637 GWh of energy for heating and cooling use and 167 GWh of electricity were produced (AGEE 2019, 6,8). The proportion of geothermal energy in the primary energy supply has risen from 0.05 % in 2005 (BUND 2012) to 0.4 % in 2018 (AGEB 2019a, 4) but is still very small.

The UBA estimates an enormous annual potential of up to 277.8 TWh of geothermal energy for heat and electricity in Germany (BUND, 4, 7). Among identified barriers for a further realisation of projects are the uncertainty of predicting sub-surface geothermal parameters, the risk of not finding energy, induced seismicity and potential gas leakages, for example of radon and hydrogen sulphides. Further obstacles are of technological and economic origin or derive from the amount of time needed for planning and developing (BGR 2019).

Students' Opinions on Geothermal Energy Development

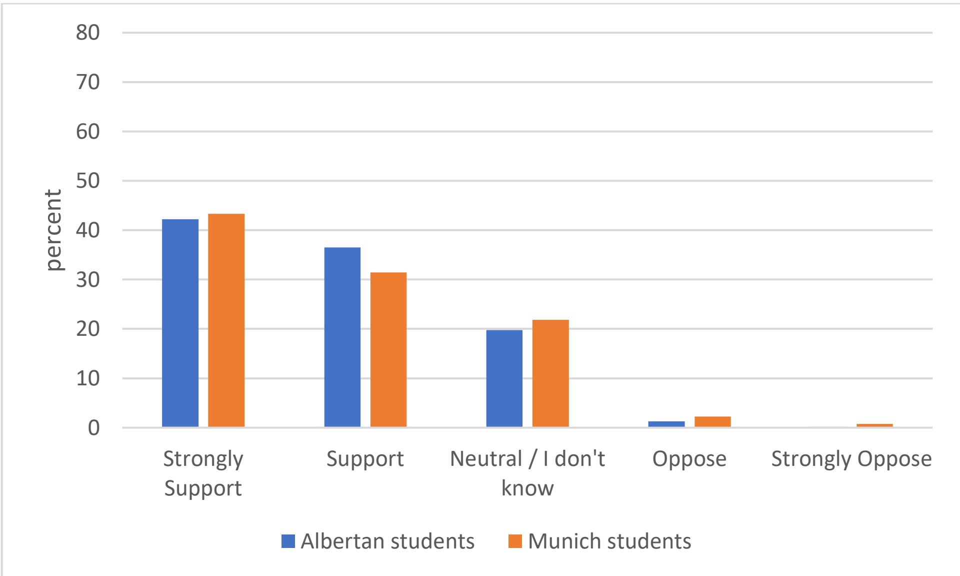

Figure 10: Results for Q5: Development of Geothermal Energy (Alberta n= 918, Munich n= 529) (Own Illustration)

Albertan and Munich students have similar levels of support for geothermal energy development - 74.6% and 77.8%, respectively, as presented in Figure 10. Thus, the development of this source is also supported by the majority of students. It is important to highlight that - as there is less support compared to solar and wind - there are not more opposing responses but rather more neutral and "I don't know" responses.

Discussion

Similar to solar and wind energy, a reason for the high support for this source in Alberta may lie in the benefits of the low-emission energy generation from this RE source, noticeable in the positive correlations between the support for geothermal expansion and CCA levels (r_s=.189, p<.01). Interestingly, no significant correlation can be found in Munich (r_s=.062, p>.05). Further research would be of value to investigate possible explanations. In both samples, the majority of the few students opposing geothermal development state that it is because the environment may degrade due to the drilling, followed by the viewpoint that other RE sources can better cover the energy demand. These opinions in combination with the knowledge of geothermal energy generation benefits may again influence the indecisive or indifferent students who choose the neutral or "I don't know" option. Furthermore, students may not be as knowledgeable about this source due to the described low prevalence of geothermal energy generation in both regions.

4.3.4 Development of Hydro Power

Hydro power means the utilization of the kinetic energy of flowing water to drive turbines connected to a generator and produce electricity (CER 2017, 8). Like geothermal power, hydro power is a renewable energy source well suited to meet baseload energy demand (Barrington-Leigh & Ouliaris 2016, 34).

Context in Alberta

The province's first hydro power plants were installed in the early twentieth century to meet the increasing demand for electricity of the steeply growing population (Government of Alberta 2019g). In 2018, hydro power accounted for 2.26 % of electricity generation in Alberta (Energy Communications 2019, 62) with 1,661 GWh generated. The installed capacity was 1,218 MW in 2017 (Statistics Canada 2019a, 2019d).

Recently, micro-hydro projects with a rather small contribution to the provincial power output have been added. Even though the best locations in Alberta are already being used for hydropower generation, there is another 11,500 MW of economic hydro potential left to be developed, according to the Canadian Hydro Association. A 2010 report for the Alberta Utilities Commission identified a total hydroelectric energy potential from Alberta's five main rivers at 53 TWh per year (Government of Alberta 2019h). Other estimates are even as high as 101 TWh per year (Barrington-Leigh & Ouliaris 2016, 26). The government officially plans to continue the use of hydro power (Government of Alberta 2019k) but among the barriers for further development are high installation costs due to the distance between consumption centres and suitable rivers in Alberta (CER 2016).

Context in Germany

Likewise, the utilization of hydro power has a long tradition in Germany. There are 7,600 facilities (UBA 2019c) and the installed capacity has risen from 3,892 MW in 1990 to 5,612 MW in 2018. Hydro power electricity generation, however, has been fluctuating between 17,000 GWh and 23,000 GWh since 1998, as can be deduced from Figure 11.

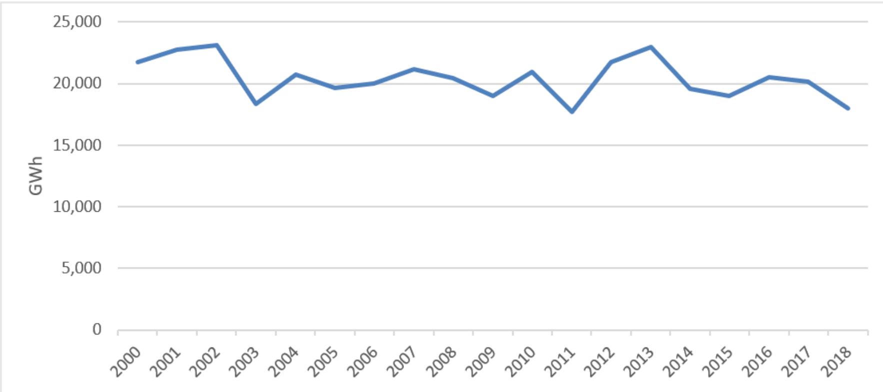

Figure 11: Electricity Generation from Hydro Power in Germany (Own Illustration based on AGEE 2019)

This is due to natural variations in water supply and level. Furthermore, severe droughts have affected hydro power generation, especially in 2017, leading to a decrease in hydro power generation to 18 TWh in 2018. The proportion of hydro power in the gross electricity generation was 2.6 % in 2018 (AGEB 2019c) similar to Alberta.

Even though 80 % of current potential is already being utilized, approximately 5 TWh could be added through optimization and modernization measures as well as the reactivation of existing plants, taking into account technical, ecological, infrastructural, and other factors (UBA 2019c).

Students' Opinions on Hydro Power Development

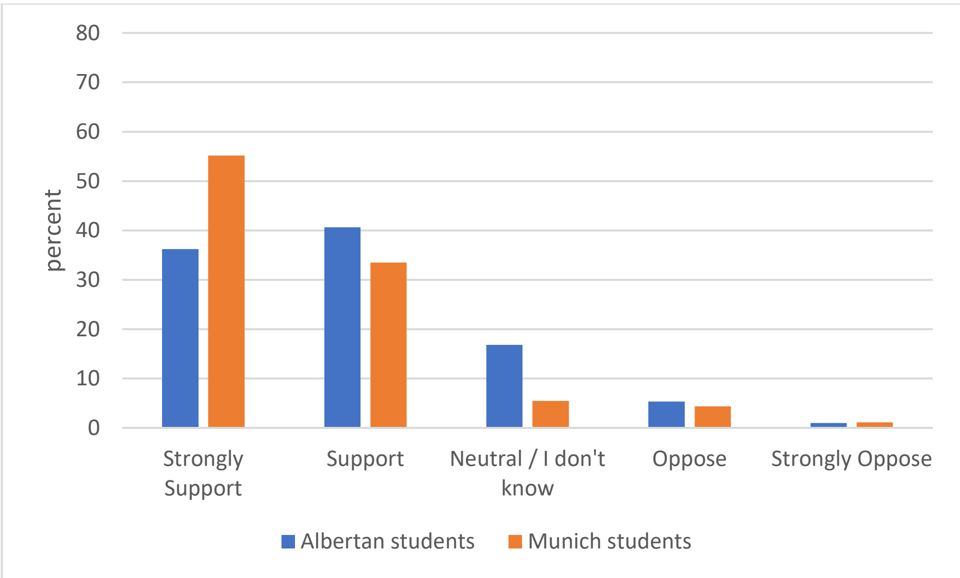

Figure 12: Results for Q5: Development of Hydro Power (Alberta n= 983, Munich n= 529) (Own Illustration)

Figure 12 shows that hydro power development receives support from the majority of both samples' students, just like the previously described RE sources. However, larger differences can be identified here. More students in Munich (89 %) are supportive compared to Albertan students (77 %) and the differences are significant (t(1,512)=-5.622, p=.000). Levels of opposition are similarly low among both samples. However, in Alberta, 17 % are indifferent or indecisive towards hydro energy development, compared to 5 % in Munich.

Discussion

Canada is among the global leaders in hydroelectric generation with 80,000 MW of installed capacity. Multiple large-scale hydro projects with over 1000 MW can be found in Quebec, Manitoba and BC. The awareness in environmental consequences of such large projects, like river fragmentation, disturbance of fish migration and downstream habitats, is high and causes discussion and conflicts over hydroelectric dam projects (CER 2017, 1, 9f; Wilt 2017). Germany has less than 0.01 % of the installed capacity in Canada. Hence, the knowledge of the drawbacks of dams may be higher in Alberta than Munich as the Albertan students are more exposed to such projects in the Canadian context. This could explain the 10 % gap in support between Alberta and Germany. Furthermore, the implementation of hydropower projects can interfere with indigenous peoples' rights and land areas in Canada (Wilt 2017), whereas there are no such conflicts in Germany as there are no indigenous peoples. In fact, of the 6 % of students who are against hydro power development in Alberta, 93 % name environmental impacts in the dam area as their reason, followed by 50 % saying that other RE sources can better cover Alberta's energy demand. Violation of indigenous rights is explicitly mentioned by four students in the comments.

> *"Indigenous rights to land are and have been ignored"*
>
> - UofA English and Film Studies Student

Likewise, 96 % of the opposing students in Munich choose dam impacts as the reason, and 65 % find other RE sources to be more suitable. It becomes clear that social and environmental concerns drive students' opinions here. These considerations may again lead more students to respond neutral or "I don't know" as compared to the previously analysed RE sources.

4.3.5 Development of Bioenergy

Bioenergy is power generated from biomass or biological material like wood, crops, plant, and other residues. It can be burned or gasified to produce power (CER 2017).

Context in Alberta

In the forested landscape of Canada, Alberta is one of the five provinces with the largest capacity and generation of biomass (CER 2017). The access to wood for fuel used to be a decisive factor for migration and settlement in the province. Biomass use, for example in small scale stove heated homes, was essential until the beginning of 1900. Then during 1910 and 1920, it was replaced by coal, hydro power, and oil, and played only a minor role in terms of growth and development until the 1973 oil crisis motivated research into alternative energy sources. Some examples for bioenergy use in Alberta today are the burning of sawmill wood waste, the manufacturing of industrial wood pellets, and biogas production for power generation (AFPA 2019).

405 GWh of electricity were produced from wood, agricultural and municipal biomass and other solid residues in 2018 (Statistics Canada 2019c). The proportion of all biomass types in electricity generation was 2.4 % in 2018 (Energy Communications 2019, 62). According to the Renewable Fuel Standard, an average of 5 % of renewable alcohol in gasoline and 2 % renewable diesel in diesel fuel is required (Government of Alberta 2019d). Information on the share of bioenergy in the heating supply could not be obtained.

However, there is more potential to be harvested. The total biomass potential in the province is estimated to be 90.4 TWh annually (Barrington-Leigh & Ouliaris 2016, 37). Forestry residuals, (by)products from agriculture, and city waste are widely available in Alberta. Most of these resources are utilized only to small extents. A UofA research study found an energy potential of 457 PJ per year, or 127 TWh, from feedstock amounts in Alberta (Nickel 2006, 3). Especially resources from the forest industry, private wood use, and industrial wood wastes are abundant in Alberta and still underdeveloped (Welling et al. n.d., 3).

Context in Germany

In Germany, bioenergy is the most important RE source for heat and electricity generation, but also for bio fuel use (BMWI 2019a). The energy source covers 11.3 % of the German heating demand and 4.6 % of the fuel demand. It had a share of 8 % in the electricity production in 2018. Figure 13 shows the absolute values for the described proportions in TWh. The installed capacity for electric generation is 8410 MW (AGEE 2019, 6ff; Bundesverband Bioenergie n.d.).

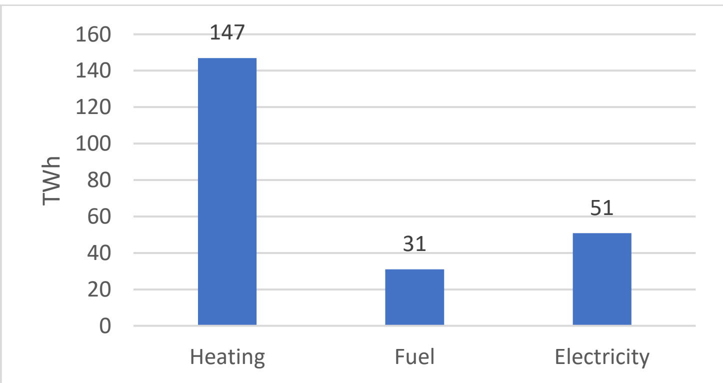

Figure 13: Energy generated from Biomass, by Use Type (Own Illustration based on AGEE 2019)

The Ministry for Economy and Energy states that further development of the source is planned, with a focus on wood-based bioenergy (BMWI 2019a). There is an estimated unused potential of 57 TWh from all biomass residues in Germany, suitable for energy generation. Yet, Germany also imports biomass material to a significant extent to cover the national demand (DBFZ 2019, 12, 36).

Students' Opinions on Bioenergy Development

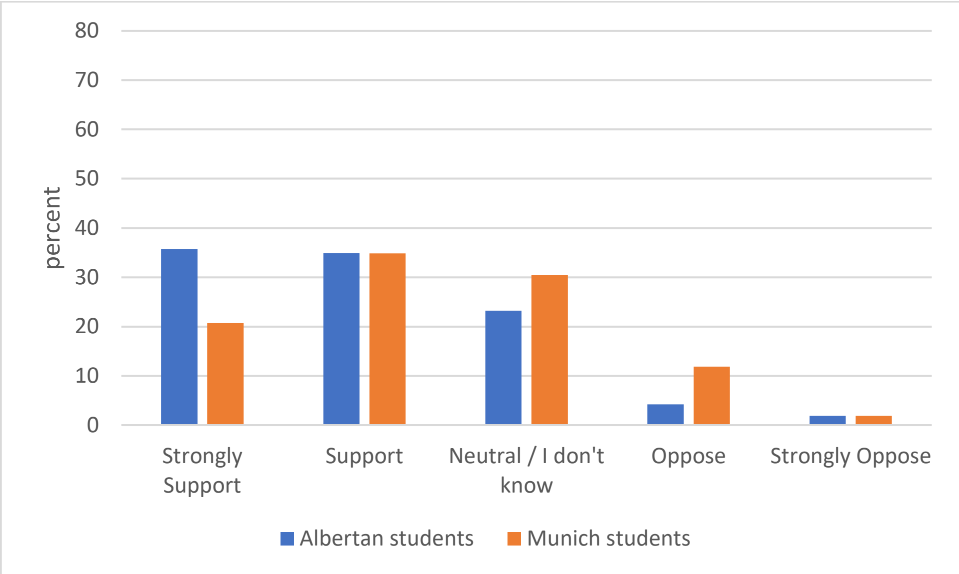

Figure 14: Results for Q5: Development of Bioenergy (Alberta n= 965, Munich n= 530) (Own Illustration)

Bioenergy is the RE source that is least supported by students (see Figure 14), though it still ranks higher than non-RE sources. The further development receives the support of the majority of both samples, with 70.6 % of Albertan students and 55.5 % of German students being in favour. However, Munich students are less supportive of biomass development than Albertan students. 8 % more of students in Munich responded neutral and "I don't know", as well as opposing.

Discussion

More energy is generated from biomass in Germany than in Alberta, as described previously. Due to the higher population density in Germany (232 people/km²) compared to Alberta (6 people/km²) (Statistics Canada 2019e; Statistisches Bundesamt 2019a), Munich students' may be more aware of biomass production because they are more often confronted with the typical monocultural fields. Therefore, awareness in negative environmental consequences of this energy generation type may be more widespread in Germany. Biomass monocultures can endanger biological diversity and ground water quality through the high use of synthetic fertilizers and pesticides. The expansion of agricultural land may result in ecosystem losses. Criticists often voice that biomass cultivation competes with other land uses, for example for food production (UBA 2019a). Furthermore, the process of cultivating, harvesting, transporting, and burning the matter still emits environmentally harmful GHGs (CER 2017, 18). In the special case of Germany, the extensive cultivation of corn for bioenergy has raised public concern and led to the coinage of the negatively connotated term "Vermaisung" (like "cornation").

Of the 14 % of students in Munich who oppose bioenergy development in Germany, the majority (72 %) name deforestation and other ecological impacts as the reason. This reflects the results of a previous study which found that students are generally supportive of RE development but advocate wood-based bioenergy less than other RE sources (Qu et al. 2011). 60 % also choose the argument that other RE sources can better cover Germany's energy demand. Specific reasons for the dismissal of bioenergy development voiced in the comments section include the following:

> *"Further extension of monocultures (and thus environmental issues like soil compaction trough [the use of] heavy agricultural machines, fertilizer application and more)"*
> - TU Chemistry Student, own translation

> *"Using food for energy production is a waste of food."*
> - LMU Education student, own translation

These concerns about ecosystem impacts and food security show that students are highly aware of potential long-term consequences of biomass production for energy generation. This awareness in the advantages as well as disadvantages drives students – especially in Munich but also in Alberta - to be less supportive of further development compared to other RE sources.

4.3.6 Development of Nuclear Power

In nuclear reactors, energy is released by splitting apart uranium atoms in order to heat water and generate steam which then turns a turbine to generate electricity (NEB 2018b).

Context in Alberta

As of 2019, there are neither nuclear power plants in Alberta nor proposed projects. The feasibility of power generation from nuclear energy in the province has been researched; for example, in a 2009 study of the general benefits and drawbacks as well as federal regulations and socio-economic impacts of nuclear energy by the Albertan Nuclear Power Expert Panel. The provincial government's reaction to this study was that no governmental money would be spend on implementing nuclear energy (NEB 2018b, 12).

Context in Germany

In contrast to this, the first nuclear power plants in Germany were built in the 1950s. The German Democratic Republic used to be the fourth largest uranium producer worldwide at a total production of 231,000 tons until 1990. Then, uranium production was stopped due to a lack of profitability (UBA 2012, 12). The International Atomic Energy Agency (IAEA) estimates that 7,000 tons of uranium are left today. But nowadays, almost the entire uranium needed is being imported to meet the domestic energy demand. Of a total number of 36 installed and operated reactors, seven are still running. According to the Atomic Energy Act described in Chapter 2.2, all plants will be shut down by 2022 (IAEA

2019). In 2018, the consumption of atomic energy in Germany was 76 TWh. Nuclear energy had a share of 11.8 % in the electricity mix (AGEB 2019c).

Students' Opinions on Nuclear Power Development

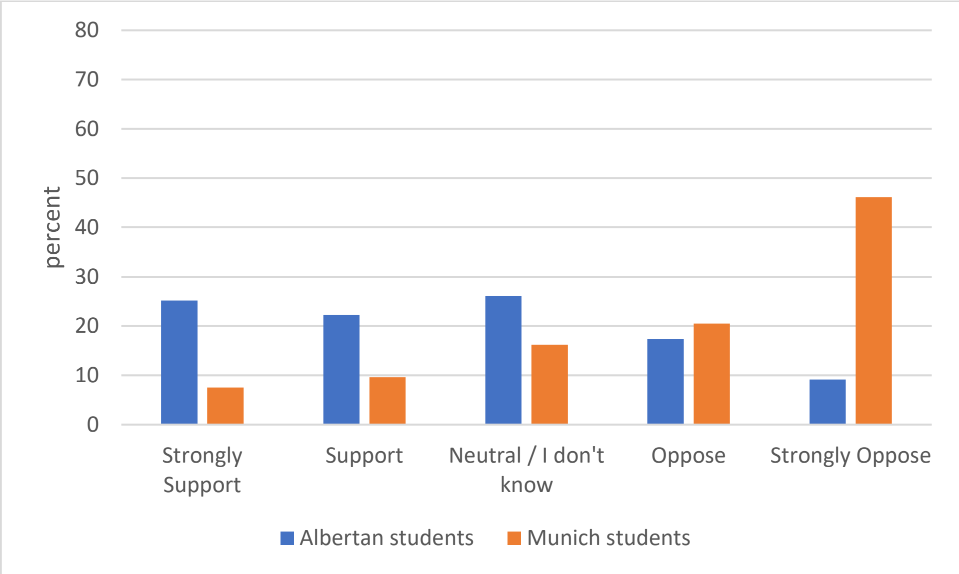

Figure 15: Results for Q5: Development of Nuclear Energy (Alberta n= 956, Munich n= 529) (Own Illustration)

There are significant differences ($t(1,485)=18.565$, $p=.000$) between Munich and Albertan students' opinions on the development of nuclear power. A clear majority of 67 % of Munich students disapprove further development of nuclear power in Germany (see Figure 15). In contrast to this, only 30 % of Albertan students oppose nuclear energy development. On the other hand, 47 % of the Albertan students state that they support nuclear power development, compared to 18 % in Munich. Every fourth Albertan student is neutral or does not know.

Discussion

The German students' opposition towards developing nuclear power reflects the general negative societal attitude towards this energy source in the country. As public awareness about the risks of atomic energy began to grow in the 1970s, resistance and protests against such projects in Germany became more and more frequent. Nuclear disasters like Harrisburg 1979, Chernobyl 1986 and Fukushima 2011 contributed to its negative perception (IAEA 2019). The government's final decision to decommission all nuclear power plants may be another factor for students to agree with the widely accepted disadvantages of the continued use of atomic energy generation and thereby influence their strong opposition.

In contrast to this, Albertan students have not been exposed as directly to nuclear energy power plants and the discussion around it in their direct environment as German students. In a province that has neither made use of this form of energy nor plans to do so, the opinions amongst students about a possible development are not unanimous. 89 % of the approving students state that they support nuclear development because no GHGs are being emitted in the energy generation process. Further 82 % choose the highly efficient transformation of energy into electricity as a reason for their standpoint. Other specific reasons given by students include the perceived safety of nuclear power plants, nuclear as a possible bridge technology for the transition to RE, and high hopes for new technologies that are under development such as thorium reactors and nuclear fusion inventions. Some students mention that Alberta's stable plate tectonics may be a good precondition for nuclear power because of the low risk of accidents due to earthquakes.

> *"[Canadian] reactors are the safest in the world and Saskatchewan has large uranium deposits, the mining of which has far less ecological impact than mining for lithium and other heavy metals necessary for solar power and the large battery banks that would be necessary for us to be entirely reliant on such fluctuating power supplies"*
> - UofA Physics student

> *"Small thorium reactors implemented worldwide may be a viable bridging technology while more RE sources develop. […]"*
> -UofA Chemical and Material Engineering student

> *"What else are we meant to do with uranium (and other resources)? Leave it to decay at no benefit?"*
> - UofA Statistics and Mathematics student

Another reason for the support voiced by some Albertan students may be the high participation rate of physics students from the UofA. Physics students constitute 5 % of the sample (n=50), and being a UofA physics student is weakly but significantly correlated with supporting nuclear energy development (r_s=.158, p<.01).

> *"More money going into nuclear power means more money going in to research around nuclear power which would mean more money going into physics research and as a physics student I'm going to support money going into what I'm interested in."*
> - UofA Physics student

However, physics students also constitute 5 % of the Munich sample (n=27) and again, a weakly significant, positive correlation is present (r_s=.124, p<.01). But the responses of the rest of the sample outweigh the effect. This shows that it is not just physics students, but also students from other faculties in Alberta who support this energy source more than in Munich.

4.3.7 Development of Natural Gas

Natural gas is a gaseous fossil fuel. It is created when marine organic matter, especially dead plankton, descends to the sea floor and is covered by sediments. Anaerobic bacteria turn it into bitumen. Over a long period of time, hydrocarbons form under high pressures and temperatures. These gases are extracted and combusted for energy generation (Glaser et al. 2017, 59f.).

Context in Alberta

As mentioned in Chapter 2.1, Alberta is a province especially rich in natural gas. According to estimations and projections created by CER, over 40 % of Alberta's resource base for natural gas of 403 trillion cubic feet, or 11.4 trillion m^3, had been exploited by the end of 2017 (CER 2019). This leaves a resource base of less than 6.84 trillion m^3. In 2018, 10.36 billion cubic feet per day, resulting in 107 billion m^3 annually, were produced, representing a stagnation compared to 2017 and the last years (Energy Communications 2019, 6). 45 % of the produced gas is exported. After coal, natural gas produced the largest proportion of electricity with approximately 37 % in 2018 (see Figure 1).

In May 2018, a Natural Gas Advisory Panel was founded (Energy Communications 2019, 38) to provide guidance and recommendations to the Energy Ministry on reacting to low natural gas prices, price volatility and market access issues in order to improve the natural gas industry. The panel advises to "aggressively grow the natural gas industry in Alberta" in order to – among other factors – "support governments' emission reduction agendas" by using natural gas as a cleaner burning fuel compared to other fossil fuels (Natural Gas Advisory Panel 2018, 8, 15).

Context in Germany

Germany's proven and probable gas reserves are significantly smaller than Alberta's. As of January 2019, there were 54.4 billion m^3 of gas reserves left. The production of gas has been declining over the past years, by 13.3 % from 2017 to 2018, due to the depletion of existing reservoirs. In 2018, 6.8 billion m^3 of gas were produced in Germany (LBEG 2019). This represents roughly 6 % of the production in Alberta.

The domestic production could only cover 6.4 % of the demand, which was 96.5 billion m^3 of pure gas (LBEG 2019), thus Germany is reliant on imports, mainly from Russia, Norway, the Netherlands, and other countries (BMWI 2019e). Gas accounted for 13 % of electricity generation in 2018 (see Figure 3), which is much less than in Alberta.

Students' Opinions on Natural Gas Development

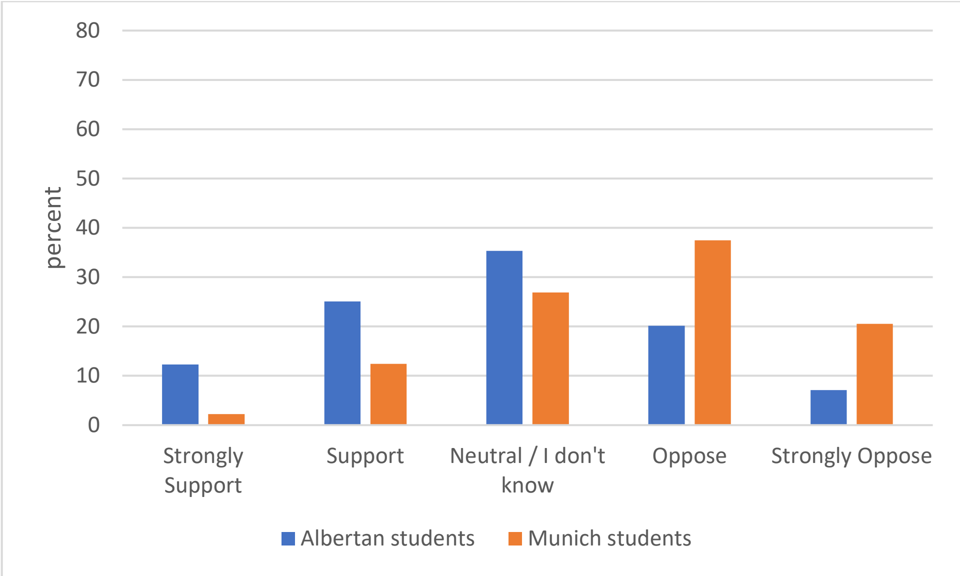

Figure 16: Results for Q5: Development of Natural Gas (Alberta n= 981, Munich n= 529) (Own Illustration)

For this fossil fuel, clear divergence can be examined regarding the opinions of Albertan and Munich students (see Figure 16). In the Albertan sample, the responses are distributed relatively evenly over the three answer options of support, opposition and neutrality. In fact, there are a little more supportive than opposing responses. In Munich however, a majority of 58 % of students disapprove of further development of natural gas. Consequently, significantly less students are supportive in Munich – only 14 % - than in Alberta - 36 %. The differences are significant ($t(1,510)=15.543$, $p=.000$).

Discussion

Natural gas takes a special position among the energy sources as it is the fossil fuel creating the least GHG emissions. However, there are controversies around its eco-friendliness as it still emits gases to some extent, and there is a risk of fugitive methane emissions in production and transmission that may outweigh the benefits (Burnham et al., 1). To better understand the motives driving students' positions towards natural gas, follow-up questions were asked both when students chose to oppose *as well as when they chose to support* the further development.

In Alberta, 76 % of the students who support natural gas development name the cleaner combustion process as the reason for their support - closely followed by the abundant supply of natural gas in Alberta (66 %). Five students comment directly on Alberta's potential as a natural gas exporter, for example:

> *"Countries converting from coal to natural gas would cut their emissions, so we should encourage them to buy our gas"*
>
> -UofA Political Science Student

…and three mention the convenience of making use of the large supply, like:

> *"(…) it is there. Might as well use it."*
> -UofC Geoscience student

> *"Honestly, that's because it's convenient."*
> -UofC Urban Studies student

Even though less Munich students support the further development of natural gas, 74 % of the supporters also say that they do so because of less emissions in the burning process compared to other fossil fuels. Six students explicitly mention the suitability of gas energy to support the energy system in cases of peak demands, especially when the rest of the system relies on RE:

> *"Comparatively clean, easy start-up and shut-down for peak demand"*
> - TUM Medicine student, own translation

Four students mention Power to Gas (PtG) solutions as the reason for their advocacy. The PtG concept refers to the production of hydrogen and subsequently methane from excess RE electricity and CO_2 (Bundesnetzagentur 2011). This shows Munich students' awareness in such modern technological approaches. However, the question did not aim at PtG solutions but at the development of the natural resource. Thus, it must be held in mind that these students supported natural gas development thinking of PtG solutions. Summing up, both in Alberta and Munich, environmentally conscious motives outweigh other motives for the support of natural gas development.

Yet, a large proportion of students vote *against* further development- more so in Munich than in Alberta. In Munich, the two reasons mentioned most often for the disapproval are the still existent emission of gases in the combustion process (80 %) and that RE sources can better cover Germany's energy demand (76 %). Students comment very often, in fact 17 times, that the dependency on other states for imports – two of them call it a geopolitical dependency - is seen as a problem.

Respectively in Alberta, the emission of harmful gases in the burning process is also the reason chosen by most students (85 %) for their disapproval of natural gas development. Almost as many (74 %) chose the impact of pipelines on ecosystems and that other RE are more suitable for energy generation. In the comments, six students explicitly mention the ecological disadvantages of fracking. Two students refer to negative economic aspects of depending on natural gas, for example:

> *"Relying so heavily on resources that have a finite limit will have severe long-term economic […] effects on Alberta when […] RE resources become more leading in the energy market."*
> - UofA Sociology student

Both regarding support and opposition for natural gas development, ecological motives are among the top reasons for students' responses. Nonetheless, supporting natural gas development is negatively correlated with the participant's score on the CCA scale (r_s=-.209, p<.01 in Munich, r_s=-.550, p<.01 in Alberta) so students who are against the development show more extreme environmental views. An additional explanation for the lower levels of support in Munich relative to Alberta may be that natural gas reserves are almost non-existent in Germany, thus it makes no sense from a geological perspective to advocate further development. However, upon examining the answers given by Munich students regarding the environmental consequences of the burning process and the dependency on imports, it becomes clear that not only the further development but also the general use and import is not supported by the majority of students.

4.3.8 Development of Oil (and Oil Sands)

Oil is a liquid fossil fuel that forms in a way similar to natural gas. The difference is that oil is generated under very specific conditions regarding temperature and pressure, in a depth of two to five km in the earth. Oil sands are a natural mix of water, sand, and bitumen, and form under less extreme temperature and pressure conditions. The processing of oils sands for energy generation is especially GHG-intensive (Glaser et al. 2017, 60f.).

Context in Alberta

In addition to gas, oil plays a major role in Alberta's economy. Approximately 444,000 Albertans – 19 % of the working population - work directly or indirectly in the field or mining, quarrying and extracting oil and gas. In 2018, investment in this industry was estimated to be 28.2 billion Canadian dollars, accounting for 59 % of the total Canadian investment in this sector (Energy Communications 2019, 24). The oil and gas sector contributes 17 % of Alberta's gross domestic product (International Institute for Sustainable Development 2018, 5).

In 2018, the total production of crude oil was 3.72 million barrel per day, equalling 190 million tons a year, which is a slight increase from 3.4 million barrel in 2017. This could fully cover the domestic demand in Alberta, which was 528 000 barrel per day in 2018 or respectively 27 million tons a year (AER 2019b, 2019c). Hence, most of Alberta's oil is exported (Energy Communications 2019, 64). As mentioned in the introduction, reserves are estimated to be as large as 21 billion tons (CER 2019; NRC 2019a).

Provincial plans to reduce oil production emissions include the CCIR, described in chapter 2.1. However, the further use of oil is encouraged by the Ministry of Energy, supporting further pipeline access to global markets to strengthen the economy. The Ministry has implemented the Energy Diversification Act in order to diversify the processing of oil. This includes a 3.7 billion dollar program from February 2019 to increase the rail capacity and deliver Alberta's oil to markets (Energy Communications 2019, 32, 37).

Context in Germany

In 2018, 2.1 million tons of oil were produced in Germany – this is approximately 1 % of the Albertan production. It can only account for 2 % of the total oil consumption in Germany which was at 103.3 million tons in 2018, constituted 34 % of the German total primary energy demand, and needs to be covered mainly by imports (AGEB 2019d; LBEG 2019, 8, 49). The production of oil has decreased 6.8 % during the last year, whereas the consumption has stayed the same. The proven and probable oil reserves in Germany are estimated to be 29 million tons - which is negligibly small in the global context (LBEG 2019,8). The most important countries for German oil imports are Russia, Norway and the United Kingdom (BMWI 2019f).

Students' Opinions on Oil (and Oil sands) Development

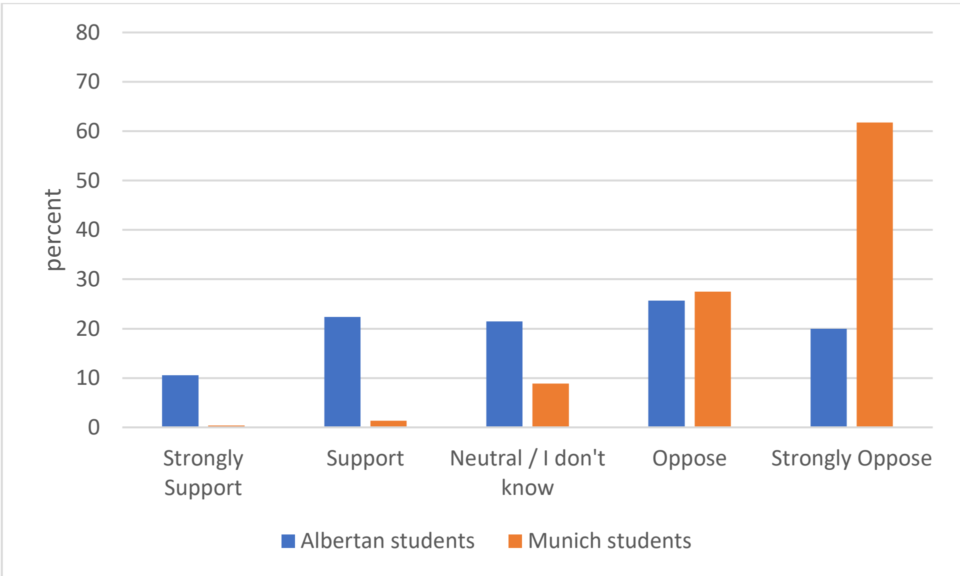

Figure 17: Results for Q5: Development of Oil (and Oil Sands) (Alberta n= 999, Munich n= 530) (Own Illustration)

Similar to natural gas, there are noticeable disparities in the opinions regarding oil development shown in Figure 17. However, Munich students' positions are even more extreme here – 89 % of Munich students are against the development of oil in Germany and only 1.7 % are supportive. In Alberta on the other hand, 33 % of students support oil and oil sands development, 21 % respond neutral or do not know, and 46 % are against further expansion.

Discussion

Again, the strong disapproval of oil development in Germany may be due to students' awareness that Germany has no significant oil resources and there is not much to be developed. Apart from that, environmental drawbacks of oil exploitation concerning GHG emissions may drive Munich students' decisions here, as support for oil development is significantly negatively correlated with the participant's score on the CCA scale (r_s=-.438, p<.01). To find explanations for the disunity of Albertan students in this topic, it is interesting to look at why 30 % chose to support oil and oil sand development. 85 % state that they are supportive because the oil industry provides an employment opportunity in Alberta. Another 73 % name the abundant supply of oil and oil sands in Alberta as their motive to support the further expansion. Economic reasons seem to be the driver here:

> *"As long as we have the need for oil and gas we should be using oil from Canada"*
> -UofA Earth and Atmospheric Sciences student

> *"We should make as much money as we can from oil while it is still demanded resource"*
> -UofA Business student

> *"Among all the energy resources whatever resource is economical should be the resource that ought to develop through market forces."*
> -UofA Engineering student

Moreover, several students perceive the oil and oil sands production in Alberta as especially environmentally friendly and socially responsible. 16 students explicitly name this as the reason for being in favour of further development, for example:

> *"By supporting the oil sands I am supporting Alberta, a democratic place where there is human rights. By not supporting the oil sands I am supporting major powers like the USA buying their oil from Saudi Arabia, Venezuela, or Nigeria, all three of which are places where there are little to no human rights."*
> - UofA Political Science student

> *"While transitioning to RE sources, and even after transitioning, the world will still need vast amounts of oil and products made from oil. Alberta is a world leader in safe and environmentally conscious extraction of oil and gas (and other natural resources), so I would like [to] see Alberta produce a larger proportion of the world's oils and gas demand."*
> -UofC Geoscience Student

The examination of further relations between the measured variables in the dataset and oil and oil sands development support in Alberta reveal a strong positive correlation with conservative political views, meaning that support for oil and oil sand development is associated with describing oneself as more conservative on the political spectrum (r_s =.607, p<.01). This correlation shall be mentioned here as it is the strongest for oil and oil sands, compared to the other sources. Moreover, the strongest negative correlation with the respondent's CCA score can be found (r_s=-.678, p<.01). Summing up, this is only a limited analysis of most important correlating factors. There is potential for an in-depth examination of other measured variables in the questionnaire which may reveal more associated factors.

4.3.9 Development of Coal

Coal is a fossil fuel that forms when plant material in swamps and peat bogs is buried by sediments. Under high temperatures and pressures, and over a long period of time, the vegetation transforms into peat and then coal. Coal types differ depending on the types of vegetation, depths of burial, temperatures, pressures and length of time since the formation (World Coal Association n.d.).

Context in Alberta

Nearly half of Alberta's land area, about 300 km², has coal bearing formations underneath (Government of Alberta 2019b, 2019f, 13). According to estimations of the AER, there are 91 billion tonnes of coal resources that can be mined (AER 2019a). Currently, there are nine mines in Alberta, producing 25 to 30 million tonnes of bituminous and subbituminous coal per year. 18 coal-fired power plants generated approximately 40 TWh in 2018, accounting for 51% of Alberta's electricity production (see Figure 1). Compared to other Canadian provinces and territories, Alberta has the largest coal fleet with an installed capacity of 6.143 MW. In 2018, the province was the largest producer of coal-fired electricity in Canada (International Institute for Sustainable Development 2018, 2).

As described in Chapter 2.1, coal-fired electricity generation will be phased out in Alberta by 2030 (Government of Alberta 2019j). In the meantime, the government is investigating ways to improve efficiency in coal electricity generation, like coal gasification (Government of Alberta 2019k).

Context in Germany

In Germany, lignite and hard coal are important for energy generation, producing 35.4% of electricity in 2018 (see Figure 3). This proportion steadily decreased from 56.7 % in 1990 and 41,5 % in 2010. Of all energy resources in Germany, lignite is the only non-RE resource which is available in large, economically extractable amounts — Germany supplies its own needs, and is the world's largest producer and consumer of this resource (IAEA 2019). The country has large reserves of approximately 36,200 Gt (BGR 2019, 27). In 2018, 166.3 million tons were produced, representing a stagnant production over the last years. It is mainly used for electricity and heat generation in power plants (BMWI 2019b).

The production of hard coal was 2.8 million tons in 2018. Bad geological conditions in Germany led to a lack of marketable production, so hard coal production was quit at the end of 2018. Germany will now rely on hard coal supply from other countries to meet its needs– in 2018, the imports were 43.2 million tons. As described in chapter 2.2, Germany plans to phase out coal-fired electricity generation until 2038 (Bundesregierung Deutschland 2019).

Students' Opinions on Coal Development

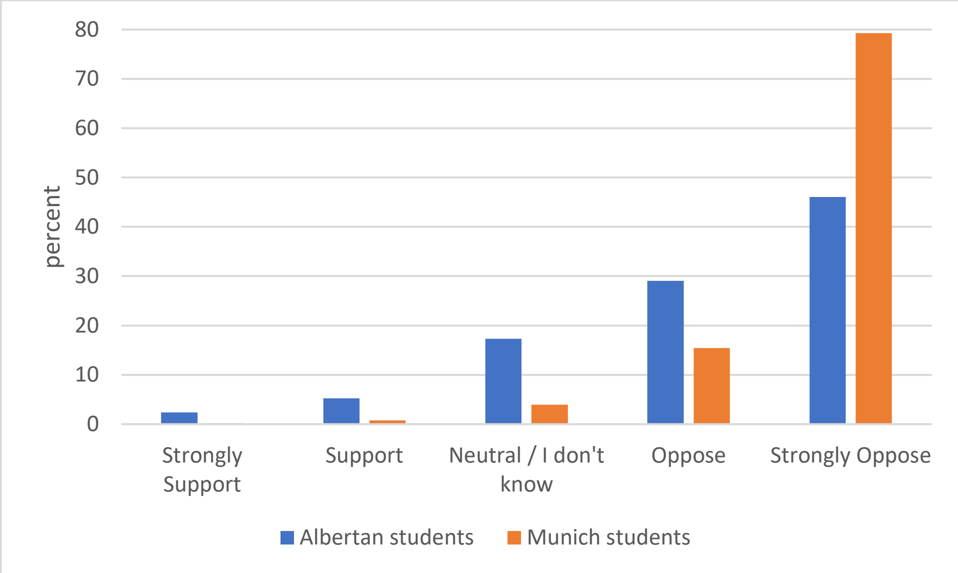

Figure 18: Results for Q5: Development of Coal (Alberta n= 988, Munich n= 529) (Own Illustration)

Compared to the other non-RE sources, the standpoints of Albertan and Munich students are more similar regarding coal development (see Figure 18). The majority of students in both samples disapprove the further development. However, Munich students' views are more extreme here as a *t*-test reveals significant differences ($t(1,517)=14.680$, $p=.000$). 94 % of students in Munich are against further development. In Alberta, 75 % oppose coal development, 17 % are neutral or do not know, and 7 % support the development.

Discussion

Again, environmental views are related to the students' positions towards this energy source. Support for coal is negatively correlated with the CCA score both in the Munich sample ($r_s=-.327$, $p<.01$) and the Albertan sample ($r_s=-.481$, $p<.01$). In Germany, there are protests against the government's plans to phase-out coal until 2038, led by the climate activist group "Fridays for Future" in Germany demanding an earlier coal phase-out, namely by 2030, in order to meet climate targets (Pohl n.d.). Therefore, the protests of this young group of activists may be an influential factor for the Munich students' opinions here and partly explain the 19 % gap in opposition between Alberta and Munich. Again, categorizing oneself more conservative than liberal on the political scale is weakly but highly significantly correlated with the support for coal production both in Munich ($r_s=.243$, $p<.01$) and Alberta ($r_s=.378$, $p<.01$).

It is interesting to find that even though coal is the only non-RE source of which Germany commands a supply abundant enough to be further expanded and deployed, the majority of Munich students still strongly oppose the further development. This standpoint differs from the Albertan students' positions regarding the most abundant non-RE resources in Alberta - oil and gas - as there are more students supporting the development of these sources. One explanation might be the overall higher CCA score of the surveyed Munich students compared to the Albertan students, indicating that the awareness in global warming issues is more widespread. Hence, these concerns may prevent Munich students from responding supportive to high-emitting energy sources even though a further development would be marketable. Furthermore, as Germany produces significantly less energy domestically than it imports in total, other branches like the car and engineering industry play a more relevant role for the country's economy compared to the energy production sector (BMWI 2019d, 5). In contrast to this, the Albertan economy heavily relies on the financial revenue from the energy industry as one of the main economic drivers. This might motivate a larger share of Albertan students to support oil and gas development in the province. It is important to highlight at this point that the position of Munich students may differ from students elsewhere in Germany as they live in Bavaria, a state without lignite mines, and a survey of students living near one of the three mining areas, like the Lausitz coalfield (BMWI 2019b), may get very different results.

5. Conclusion

In this thesis, an analysis of students' opinions on the further development of energy sources in Alberta and Germany was conducted. The presented results show that in general, students in Alberta and in Germany are nearly unanimously supportive of RE development, especially wind and solar energy. Therefore, the first hypothesis proposed in this thesis can be confirmed in the sample. Considering non-RE sources, opinions disperse widely between the Albertan and Munich sample, especially regarding nuclear, oil, and gas energy. This shows that positions towards these energy sources in fact depend on the local context. Thus, the second hypothesis in this thesis, proposing that perceptions differ due to geographical contexts, can as well be confirmed. The students in Munich are very opposed to any type of fossil fuel development. In Alberta, the viewpoints vary depending on the source – more students are supportive, neutral, or undecided towards the development of natural gas, oil and nuclear.

Potential explanations outlined in this thesis refer to the importance of the oil and gas industry for the Albertan economy and to the significant correlations between students' standpoints and their CCA levels as well as political views. Further regression analysis is necessary to investigate whether CCA levels and political views can in fact predict a student's opinion or may become insignificant when controlling for other factors. More associations are to be analysed between opinions on energy sources and factors like faculty, age, educational status, knowledge about energy issues, gender, country of origin, and living situation. Due to the scope of this thesis, these factors could not be taken into account yet and will be investigated in further analyses.

These findings add to the knowledge base of students' demand for energy sources. Although this thesis can unfortunately not fulfil the wishes made by some students:

> *"Let's go CO2 neutral until 2040!"*
> -LMU BWL student

> *"Save the Earth, thank you."*
> -UofA Environmental Conservation Science student

It aims to send a message to decision-makers in the energy industry and contribute to energy development processes by disclosing information on students' acceptance and support for RE and non-RE sources. This thesis is appealing to acknowledge students' high support for RE expansion and to further drive a sustainable transition of the energy sector, which is urgently needed in order to mitigate climate crisis. The high support for the further RE development among students may be a positive precondition for a future RE expansion in Alberta and Germany. The supportive students may seek employment in the RE sector in the future or drive political and economic changes in the energy sector in another way during their careers - may it be at their workplace, by voting for a specific party, or by joining a local energy initiative. However, energy transition measures are urgently needed already now. Meeting the global climate target of keeping the temperature rise below two degrees Celsius is technically feasible, but immediate action is crucial (IREA 2018, 8) The examination of specific survey comments shows that several students are aware of the need to take climate action in the energy sector.

> *"In the wake of climate change and global warming it is important for governments and people alike to focus entirely on RE despite the economic concerns associated with it. The extent of human destruction on the environment is adverse and should be addressed with complete urgency and responsibility."*
>
> -UofA Engineering student

"The planet is burning and people are seeing the impacts in their lives, that's why they care now."

-UofA Biochemistry student

Some students even voice ideas about what measures could be taken.

"Industry should be forced by the law to use RE to a specific amount."

-LMU Business Development student, own translation

"[…]The best way forward is for current energy companies to lead the charge and invest into RE options."

-UofC Geoscience student

"The socialistic way: Take the power from the few who are ruining the world (CEOs and politicians) and give it to the population. Political decisions will be made by the population and companies will be led democratically by all employees, (…) achieving the transition towards sustainable business and away from greed for profit."

-LMU information and language processing student, own translation

From these comments, it can be deduced that several students are contemplating more and less extreme mechanisms of sustainable transition and show great willingness to engage in this topic. This and the high number of survey responses prove that the surveyed students in Munich and Alberta care very much about energy transition and energy issues. There is great potential for further collaboration between students from both regions, as it is already happening in the scope of ABBY-Net summer schools. Both sides can learn much from the different geographical, socio-economic, and political situations regarding energy in Germany and Alberta. Lessons from different approaches as well as future plans can be shared. Thereby, solutions for energy issues can be developed.

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Appendix

Appendix 1 Questionnaire "Identifying Students' Position towards Energy Sources" by the example of the UofA questionnaire. Changes in the Munich survey are marked in *italic.*

Appendix 2 Flyer, handed out to students at the UofA campus.

Appendix 3 Poster, put up on bulletin boards around the UofA campus.

Appendix 1

Introduction of the UofA & UofC Questionnaire
Study Title: Identifying Students' Position towards Energy Sources

Research Investigators:
Department of Resource Economics and Environmental Sociology

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Dear Participant,
Thank you for your interest in this survey! By taking part, you are making a difference in energy- and environment-related research. We will be asking you about your opinion on the use and development of different energy sources in Alberta. Please take the time to read through the questions and answer them to the best of your knowledge. The survey will take between 5 to 10 minutes to complete. Your responses will help us to better understand students' perception and behaviour towards energy types and contribute to a knowledge base of the demand for energy sources among students.
When the term "Renewable Energy" is used in this survey, it refers to energy sources that are replenishing within the human timescale. This includes sources like solar, wind, hydroelectricity, geothermal energy and biomass.
The survey is anonymous and completely voluntary. You can choose to skip questions that you prefer not to answer and quit the survey at any time, with no data being stored. Please be ensured that your responses will be completely confidential. The data will be encrypted, stored on secure servers and kept for a minimum of 5 years, as required by the University of Alberta Policy. After that, the data will be destroyed in case it is not useful for researchers anymore. Only the Research Team will be able to access the data. There is no risk of participation in this survey. Please be informed that we cannot withdraw your response once you've submitted it.
If you have any questions regarding this survey, please contact Janina Fuchs at jfuchs@ualberta.ca. The plan for this study has been reviewed by a Research Ethics Board at the University of Alberta. If you have questions about your rights or how research should be conducted, you can call (780) 492-2615 and refer to the ethics application number Pro00094155. This office is independent of the researchers.
By proceeding with the survey, you indicate that you agree to participate in the research study described above.

Sincerely,
The Research Team

Introduction to the Munich Questionnaire

Dear Participant,

Thank you for your interest in this survey! The aim of this study is to examine and compare Canadian and German students' positions towards energy sources. In September and October 2019, the same survey was conducted at the University of Alberta in Edmonton and the University of Calgary, Canada, with approximately 1000 students. By taking part, you are making a difference in energy- and environment-related research. We will be asking you about your opinion on the use and development of different energy sources in Alberta. Please take the time to read through the questions and answer them to the best of your knowledge. The survey will take about five minutes to complete. Your responses will help us to better understand students' perception and behavior towards energy types and contribute to a knowledge base about the demand for energy sources among students.

When the term "Renewable Energy" is used in this survey, it refers to energy sources that are replenishing within the human timescale. This includes sources like solar, wind, hydroelectricity, geothermal energy and biomass.

The survey is anonymous and completely voluntary. You can choose to skip questions that you prefer not to answer and quit the survey at any time, with no data being stored. Please be ensured that your responses will be completely confidential. The data will be encrypted, stored on secure servers and kept for a minimum of 5 years, as required by the University of Alberta Policy. After that, the data will be destroyed in case it is not useful for researchers anymore. Only the Research Team will be able to access the data. There is no risk of participation in this survey. Please be informed that we cannot withdraw your response once you've submitted it.

If you have any questions regarding this survey, please contact Janina Fuchs at janina.fuchs@campus.lmu.de. The plan for this study has been reviewed by a Research Ethics Board at the University of Alberta. If you have questions about your rights or how research should be conducted, you can call (780) 492-2615 and refer to the ethics application number Pro00094155. This office is independent of the researchers. This research project has been reviewed and approved by the Conjoint Faculties Research Ethics Board at the University of Calgary.

By proceeding with the survey, you indicate that you agree to participate in the research study described above.

Sincerely,
The Research Team

Q1

Are you a ...?

Please choose the option that best describes your education status.

- ○ Undergraduate Student
- ○ Masters Student
- ○ PhD Candidate

Q2 Are you an international student?

- Yes
- No

If Q2 = Yes

Q2.1 Where are you from?

____

Q3 What is your faculty?*

Agricultural, Life and Environmental Sciences (1)	Extension (8)	Pharmacy and Pharmaceutical Sciences (15)
Alberta School of Business (2)	Graduate Studies and Research (9)	School of Public Health (16)
Arts (3)	Kinesiology, Sport, and Recreation (10)	Rehabilitation Medicine (17)
Augustana Campus (4)	Law (11)	Science (18)
Campus Saint-Jean (5)	Medicine & Dentistry (12)	St. Joseph's College (19)
Education (6)	Native Studies (13)	St. Stephen's College (20)
Engineering (7)	Nursing (14)	Other/ I don't know (21)

**Corresponding drop down menus for the faculties of the UofC, LMU and TU. Open text entry for othertertiary institutions in Munich.*

Q4 What is your department?

If you don't know your department, please enter the program you are in.

____

Q5 In general, to what extent do you support or oppose further development of the following energy sources in Alberta / *Germany*?

	Strongly Support	Support	Neutral	Oppose	Strongly Oppose	I don't know
Oil (and oil sands*)	○	○	○	○	○	○
Wind	○	○	○	○	○	○
Hydro	○	○	○	○	○	○
Geothermal	○	○	○	○	○	○
Nuclear	○	○	○	○	○	○
Coal	○	○	○	○	○	○
Solar	○	○	○	○	○	○
Bioenergy (from wood, waste, plants, ...)	○	○	○	○	○	○
Natural gas	○	○	○	○	○	○

*(*excluded from the Munich survey)*

If Q5 = Strongly Support / Support for oil and oil sands

Q5.1

Specifically, why do you support the development of oil (and oil sands*)?

Please choose all that apply.

- ☐ Currently inexpensive and easy to extract
- ☐ Abundant supply, especially in Alberta / *Germany*
- ☐ The oil industry provides an employment opportunity in Alberta / *Germany*
- ☐ Production (infra)structures are already established
- ☐ Reliable and capable of generating large amounts of power
- ☐ A member of my family works in this sector
- ☐ Other, please describe: ____

*(*excluded from the Munich survey)*

If Q5 = Oppose / Strongly Oppose for wind

Q5.2 Specifically, why do you oppose the development of windpower?
Please choose all that apply.

- ☐ The wind does not blow all the time, so it's not worth installing wind turbines
- ☐ High initial investment and/or ongoing maintenance costs
- ☐ Disruptive visual impact and extensive land use
- ☐ There is too little / no windpower potential in Alberta / *Germany*
- ☐ Too little is known about the technology
- ☐ Fossil fuels can better cover Alberta's / *Germany's* energy demand
- ☐ Other renewable sources can better cover Alberta's / *Germany's* energy demand
- ☐ Other, please describe: ____

If Q5 = Oppose / Strongly Oppose for hydropower

Q5.3 Specifically, why do you oppose the development of hydropower?
Please choose all that apply.

- ☐ Environmental impacts change the environment in and around the dam area
- ☐ Hydroelectric dams are expensive to build
- ☐ Dams may be affected by drought
- ☐ There is too little / no hydropower potential in Alberta / *Germany*
- ☐ Too little is known about the technology
- ☐ Fossil fuels can better cover Alberta's / *Germany's* energy demand
- ☐ Other renewable sources can better cover Alberta's / *Germany's* energy demand
- ☐ Other, please describe: ____

If Q5= Strongly Oppose / Oppose geothermal

Q5.4 Specifically, why do you oppose the development of geothermal power?
Please choose all that apply.

- ☐ Environment may degrade because of the drilling
- ☐ Expensive start-up costs
- ☐ Wells could eventually be depleted
- ☐ There is too little / no geothermal potential in Alberta / *Germany*
- ☐ Too little is known about the technology
- ☐ Fossil fuels can better cover Alberta's / *Germany's* energy demand
- ☐ Other renewable sources can better cover Alberta's / *Germany's* energy demand
- ☐ Other, please describe: ____

If Q5 = Strongly Support / Support Nuclear

Q5.5 Specifically, why do you support the development of nuclear power?
Please choose all that apply.

- ☐ No greenhouse gases or CO2 emissions in the energy generation process
- ☐ Efficient at transforming energy into electricity
- ☐ Uranium reserves are abundant
- ☐ Refueled yearly (unlike coal plants that need a lot of coal every day)
- ☐ Other, please describe: ____

If Q5 = Strongly Support / Support coal

Q5.6 Specifically, why do you support the development of coal?

Please choose all that apply.

- ☐ Abundant supply
- ☐ Currently inexpensive to extract
- ☐ Reliable and capable of generating large amounts of power
- ☐ The coal sector provides employment opportunity in Alberta / *Germany*
- ☐ A member of my family works in this sector
- ☐ Other, please describe: ____

If Q5 = Strongly Oppose / Oppose solar

Q5.7 Specifically, why do you oppose the development of solarpower?

Please choose all that apply.

- ☐ High initial investment
- ☐ Dependent on sunny weather
- ☐ Supplemental energy may be needed in low sunlight areas
- ☐ Disruptive visual impacts and extensive land use
- ☐ The panels' material may be sourced unsustainably
- ☐ Large physical space for PV cell panels is required
- ☐ Limited availability of polysilicon for panels
- ☐ There is too little / no solarpower potential in Alberta / *Germany*
- ☐ Too little is known about the technology
- ☐ Fossil fuels can better cover Alberta's / *Germany's* energy demand
- ☐ Other renewable sources can better cover Alberta's / *Germany's* energy demand
- ☐ Other, please describe: ____

If Q5 = Strongly Oppose / Oppose bioenergy

Q5.8 Specifically, why do you oppose the development of bioenergy?
Please choose all that apply.

- ☐ Deforestation and further ecologic impacts due to biomass production
- ☐ To some extent, methane and nitrous oxides are being emitted, so it's not entirely clean
- ☐ Bad smell can be involved
- ☐ Plants require a lot of water
- ☐ Less efficient than fossil fuels
- ☐ Emissions from transportation from source to production site may be high
- ☐ May use some fossil fuels in conversion
- ☐ There is too little / no biopower potential in Alberta / *Germany*
- ☐ Too little is known about the technology
- ☐ Other renewable sources can better cover Alberta's/ *Germany's* energy demand
- ☐ Fossil fuels can better cover Alberta's / *Germany's* energy demand
- ☐ Other, please describe:

____

If Q5 = Oppose / Strongly Oppose natural gas:

Q5.9 Specifically, why do you oppose the development of natural gas?
Please choose all that apply.

- ☐ Burns cleanly, but still has CO_2 emissions, so it's still harmful to the environment
- ☐ Pipelines impact ecosystems
- ☐ Risk of gas explosions
- ☐ Too little is known about the technology
- ☐ Other Fossil fuels can better cover Alberta's / *Germany's* energy demand
- ☐ Renewable sources can better cover Alberta's / *Germany's* energy demand
- ☐ Others, please describe: ____

If Q5 = Support / Strongly Support natural gas

Q5.10 Specifically, why do you support the development of natural gas?
Please choose all that apply.

- ☐ Currently inexpensive to extract
- ☐ Abundant supply, especially in Alberta / *Germany*
- ☐ Production (infra)structures already established
- ☐ Less emissions in the burning process compared to other fossil fuels
- ☐ Safe and easier to store than other fossil fuels
- ☐ A member of my family works in this sector
- ☐ Cheaper than other fossil fuels
- ☐ Other, please describe: ____

Q6 Now, we would like to ask your opinion on the use of renewable energies as an electricity source at your current residence.
To what extent do you agree with the following statement?

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	I don't know
I would like to use electricity from renewable energies at my current residence.	○	○	○	○	○	○

If Q6 = Strongly Agree / Agree / Neutral / I don't know

Q6.1 Would you be willing to pay more money for electricity from renewable energies at your current residence?

- ○ No.
- ○ Yes, I would be willing to pay up to 10 Dollars more per month.
- ○ Yes, I would be willing to pay up to 25 Dollars more per month.
- ○ Yes, I would be willing to pay up to 50 Dollars more per month.
- ○ Yes, I would be willing to pay more than 50 Dollars per month.

Q6.2 Can you influence the choice of electricity supplier at the place where you live?

- ○ Yes
- ○ No
- ○ I don't know

Q6.3 To what extent do you agree with the following statement?

	Strongly agree	Agree	Disagree	Strongly Disagree
I know how to change to a renewable electricity supplier.	○	○	○	○

If Q6.3 = Disagree / Strongly Disagree

Q6.3.1 To what extent do you agree with the following statement?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	I don't know
I need more information on how to purchase electricity that comes from renewable sources.	○	○	○	○	○	○

If Q6 = Disagree / Strongly Disagree

Q6.4
Why would you not like to use renewable energies at your current residence?
Please choose all that apply.

- ☐ The costs are too high
- ☐ I don’t trust or support the technology
- ☐ I cannot influence the electricity source at my residence
- ☐ Other, please describe: ____

Q7 **Community renewable energy projects** are projects where citizens participate in the generation of energy from renewable sources. Citizens (private households, communities etc.) form a legal structure to collectively finance and establish renewable energy projects, for example wind or solar farms. Renewable electricity generated by such projects is then collectively sold, for example to local energy utilities, and profits are split among participating citizens.

	1	2	3	4	5
Now or in the future, how willing would you be to invest money in a community energy project in your municipality?	○	○	○	○	○

If Q7 = 3 / 4 / 5

Q7.1 How much money would you like to invest per month?

Q8 Now, we would like to find out more about your knowledge of the Albertan / *German* energy system.
Which is the main electricity supplier company in Edmonton / Calgary / *Munich*?

____

Q9 What percentage of Alberta's */ Germany's* electricity generation comes from renewable sources?

____

Q10 *UofA/UofC questionnaire:* Do you consider these statements to be true or false?

	True	False
Living within 2 km of a wind turbine is a health risk.	○	○
In their lifetime, wind turbines will not recover their cost of installation.	○	○
Alberta is too far north for solar panels to be an effective source of energy.	○	○

Q10 Munich questionnaire: Do you consider these statements to be true or false?

	True	*False*
Photovoltaic plants generate more energy at warmer temperatures.	○	○
In their lifetime, wind turbines will not recover their cost of installation.	○	○
It's not possible to generate enough electricity from renewable sources to fully cover Germany's electricity demand (due to weather conditions, such as too little wind).	○	○

Q10 Is the topic of renewable energy technologies part of the program of your degree?

- ○ Yes, it is the focus of my program
- ○ Renewable energies are often discussed in my program
- ○ The topic of renewables is sometimes discussed in my program
- ○ Renewables are rarely or never mentioned in my program
- ○ I don't know
- ○ I'm not in a program (yet)

Q11 How knowledgeable do you consider yourself on renewable energies?

- ○ I am very knowledgeable on renewable energy technologies and their impacts
- ○ I am somewhat knowledgeable on renewable energy technologies and their impacts
- ○ I know a little about renewable energy technologies and their impacts
- ○ I know nothing about renewable energy technologies and their impacts

Q12 In this section, we want to find out about your general attitudes and perceptions related to environmental issues and technological change in Alberta / *Germany*.
To what extent do you agree with the following statements?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	I don't know
Q12.1 The concerns about climate change as a danger to nature, animals and humankind are exaggerated.	○	○	○	○	○	○
Q12.2 The use of fossil fuels is harmful to the environment.	○	○	○	○	○	○
Q12.3 Alberta / *Germany* has a responsibility to greatly reduce its CO2 emissions.	○	○	○	○	○	○
Q12.4 I am ready and willing to change my lifestyle to reduce my ecological footprint.	○	○	○	○	○	○
Q12.5 I am willing to engage in environmental activism, like climate protests or volunteering with the university sustainability council.	○	○	○	○	○	○
Q12.6 Renewable energy technologies have negative impacts on landscapes.	○	○	○	○	○	○

Q13 What is your opinion on energy education in Alberta / *Germany*?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	I don't know
In general, I would welcome more education on renewable energy technologies in schools and universities in Alberta / *Germany.*	○	○	○	○	○	○
In general, I would welcome more education on environmental issues in schools and universities in Alberta / *Germany*.	○	○	○	○	○	○

Q14 Which of the following factors do you believe to be the greatest barrier to renewable energy development in Alberta / *Germany?*
Please choose one.

- ○ Natural potential as a barrier for renewable energy generation in Alberta / *Germany*
- ○ Policy and / or regulatory barriers
- ○ Lack of societal support
- ○ Economic viability of renewables, like investment costs
- ○ The technology is not yet developed enough to be applied in Alberta / *Germany*
- ○ Lack of human resources, like labour
- ○ Infrastructure and grid barriers
- ○ Other, please describe: ____

Q15 You have made it to the end of the survey - Thank you! Please answer these final questions about your person to complete the survey.
How old are you?

____

Q16 What is your gender?

○ Female

○ Male

○ Prefer not to say

○ Prefer to self-describe: ____

Q17 What is your housing situation? I live...
Multiple answers are possible.

▢ With my parents and / or other family members

▢ In a student hostel or dorm

▢ In a shared apartment or house

▢ Alone

▢ With my partner

▢ With my children

▢ None of the above

▢ Prefer not to say

Q18 What percentage of your monthly income goes towards rent and school expenses?

____

Q19 On a scale from 1 (very conservative) to 7 (very liberal):

	1	2	3	4	5	6	7	Prefer not to say	I don't know
How would you describe your political views?	○	○	○	○	○	○	○	○	○

Q20 Is there any question or comment you would like to leave for the research team?

____

Appendix 2

What is **your opinion** on **energy development in Alberta**?
Please participate in my 5-to10-minute survey:
Link: https://bit.ly/2mkMGLz

Thanks a lot!

Department of Resource Economics and Environmental Sociology
Faculty of Agricultural, Life & Environmental Sciences

Appendix 3

Survey for University of Alberta Students

What do you think about energy development in Alberta?

My research survey examines the **opinions of UofA students on energy sources**.
Estimated time between 5 and 10 minutes.

Please participate! Thanks!

Link: https://bit.ly/2mkMGLz

QR-Code:

Principal Investigator: John Parkins

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Statutory declaration

I hereby declare that I have authored this thesis independently and that I have not used any other sources or resources than declared in the list of references. Furthermore, I have explicitly marked all literal quotations or material quoted by content from a specific source.

This thesis has not previously been handed in, and it has not been published.

Janina Fuchs

Janina Fuchs   Munich, 16th of December 2019

Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die vorliegende Arbeit komplett eigenständig und ohne fremde Hilfe angefertigt habe. Sämtliche Textpassagen, die dem Werk anderer Autoren entweder im Wortlaut oder dem Sinn nach entnommen wurden, sind durch genaue Quellenangaben hervorgehoben.

Diese Arbeit wurde bisher keiner anderen Prüfungsbehörde vorgelegt, und wurde bisher auch nicht veröffentlicht.

Janina Fuchs

Janina Fuchs   München, 16. Dezember 2019