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A Local District Heating Project with Integrated Greenhouses in Germany – From High Acceptance to an Innovating Heating Price System

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ABSTRACT

The German Molasse Basin in the south of Germany harbors an enormous geothermal potential. Temperatures in the aquifers range from 70°C to 160°C, rendering the region an excellent location for deep geothermal energy projects. A perfect example for the technical and economical use of geothermal energy in this region is the award-winning project in the municipality of Kirchweidach, a 2,600-inhabitant town in southeast Bavaria. This project was the first in Germany, to provide an agricultural business with geothermal heat energy via a local district heating network. In 2011, the project started with a drill for the production well (with a depth of 3850m and a length of 5133m), and an injection well (with a depth of 3800 m and a length of 4937 m) in the north of Kirchweidach. A private project developer conducted the doublet drilling. The hot water temperature of the production well is approximately 125°C and equips the, in 2014, newly built district-heating network of the small town as well as one of the largest greenhouses in Bavaria with CO_2-free heat energy. The district heating network supplies private homes and public buildings with an annual heat demand of 13 GWh_{th}, simultaneously providing the whole greenhouse with an annual heat demand of approximately 108 GWh_{th}. A vegetable farmer near the drilling site started building his greenhouse in 2014 with an initial cultivation area of 12 ha, which he expanded to 20 ha in 2015. A steady supply of renewable base-load heat energy from the geothermal plant supplying the greenhouse makes it possible to farm bell peppers, tomatoes from January to November and strawberries from March to May and October to December. Tomatoes from this one greenhouse now accounts for a fifth of all tomatoes sold by a major German supermarket chain in the state of Bavaria. Nearly 7.5 million litres of fuel used for the greenhouse are saved yearly. The municipality bypasses approximately 1.6 million transport-kilometres due to imports from Spain and 400.000 km from the Netherlands. Bavaria increased its self-sufficiency with tomatoes from 7% to 11% and bell peppers from 2% to 7%. The constant heat demand of the greenhouse is a perfect use of the potential of geothermal energy. To ensure a high connection density in the district heat network for the economic and ecological success of the project, a high acceptance of the inhabitants of the small town was necessary. By informing the inhabitants about used technologies and about required steps throughout all project-phases, citizens were educated about the specifications of the project starting from the early stages. The involvement of the greenhouse and an innovating heating price system were greatly emphasized and generated high acceptance rates. The innovating heating price system is based on an opportunity cost approach. To determine the heating price, the price system takes foregone electricity sales for feed-in tariffs under the German Renewables Act into account. Additionally, the outside temperatures, which have a significant impact on the efficiency of the electricity generation unit, are considered. This opens up the possibility to extract a variable volume flow to supply the district heating network, concurrently generating electricity without affecting the operator of the power plant adversely.

1. INTRODUCTION

This paper examines the symbiotic potential of geothermal energy and greenhouses. Geothermal energy is thermal energy, or heat, derived from the sub-surface of the earth. The most important components are deep Mesozoic sediments. In Germany, these sediments are located in three areas, namely the north German basin, the Upper Rhine Graben and the South German Molasse Basin. After conducting the first successful deep geothermal drillings and projects in the early 2000s, the South German Molasse Basin became the centre of attention to many project managers, as it provides an aquifer with temperatures above 100 °C and flows above 80 l/s and up to 200 l/s per doublet drilling, granting the generation of electricity.

Besides the heating demand and the electricity demand, everyday consumption has a considerable impact on the county's carbon footprint. Depending on consumer patterns, food production requires more or less CO_2. Figure 1 illustrates the yearly CO_2 emissions of an average consumer and shows that meat and dairy products account for the largest share of CO_2 emissions. Nevertheless, vegetable and fruit products account for 13.5 % of the total CO_2 emissions. The carbon footprint of vegetable and fruit is heavily dependent on their origin and the respective transport from the production site to the supermarkets.

In Kirchweidach, a 2,600-inhabitant town in southern Bavaria, Germany, geothermal energy is predominately used for heating, specifically district heating systems. In 2011, the project started with a drill for the production well (with a depth of 3,850 m and a length of 5,133 m), and an injection well (with a depth of 3,800 m and a length of 4,937 m) in the north of Kirchweidach.

Vegetable farmer Steiner is the biggest costumer for the district heating system and heats his greenhouse with geothermal energy, being the first agricultural business to derive geothermal heat via a local district heating system. Following successful contract negotiations, the supply of geothermal energy started as early as 2013, allowing cultivation to begin ahead of schedule. Today, the total amount of heating needed for the 20-hectare large green house amounts to approximately 108 gigawatt-hours yearly. Vegetable farmer Steiner produces vine tomatoes, cucumbers, cocktail tomatoes, strawberries and bell peppers for the regional market. The greenhouse is able to meet the demand of approximately 1 million citizens, located in Bavaria. Specifically, the tomatoes from this greenhouse accommodate one fifth of all tomatoes sold by the supermarket chain REWE in the state of Bavaria. In sum, every tenth tomato in Bavaria, the German state inhabiting a population of 13 million people, comes from Kirchweidach.

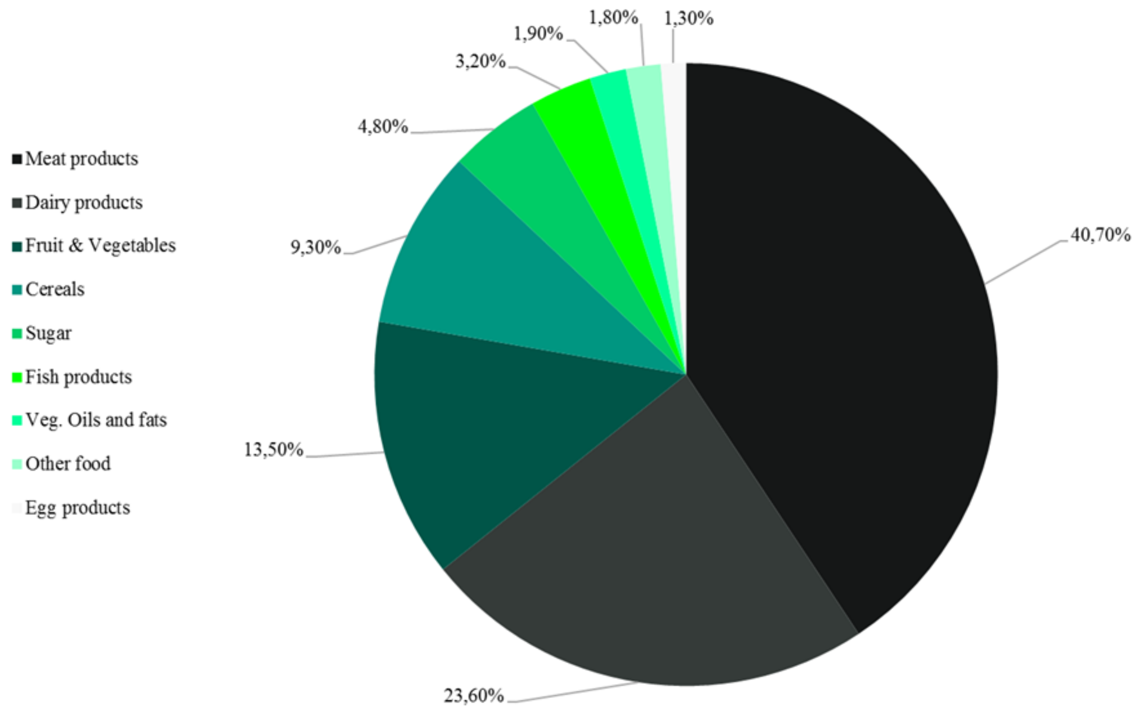

Figure 1: Yearly CO_2-emissions caused by food consumption per capita in percent. Source: WWF (2012)

Numerous studies have examined and compared locally produced goods versus long-range imports. Greenhouse emission substantially varies, dependent on surrounding determinants. The empirical findings about greenhouse products are bifurcated. Carlsson-Kanyama (1998) and Theurl et al. (2014) illustrate that for the production and consumption of food, CO_2, CH_4, N_2O and hydrofluorocarbons, some of the major greenhouse-gases, are intrinsic negative externalities and are, therefore, suitable to estimate emissions. Standard life cycle assessment uses these respective components to estimate emissions.

A survey conducted in 2006 by the Institute of Grocery Distribution (IGD) states that 60% of the respondents believe freshness was the most assertive argument to prefer local food. In addition, 29 % testified that they selected local food because of the support for local producers. Of the respondents, 24 % favoured local food for environmental reasons, perceiving locally produced food as more sustainable. Despite the common perception that local production is sustainable, empirical studies have been calumnious towards this public notion. Edwards-Jones et al. (2008) and Schlich and Fleissner (2005) introduce the argument of "Ecologies of scale". Because producers of considerable size inevitably increase their economies of scale, importing products can potentially be less environmentally pernicious relative to local goods.

Hauwermeiren et al. (2007) argue that locally produced food is not always beneficial. Their research examines the energy necessary during indispensable stages of the lifecycle of selected food items. The study focuses on tomatoes specifically. His study argues that locally produced tomatoes can be worse for the environment, when produced in fossil fuel intense greenhouses. Figure 2 illustrates a conceptual framework of how emissions for vegetable and fruit production, e.g. for tomatoes, are examined. The graphic shows the numerous stages of the supply chain could potential be subject to emissions, inevitably altering the sustainability of production.

Williams (2007) studied the difference between roses imported from Kenya and roses produced in the Netherlands. His findings illustrate that roses from Kenya produced less emission, even when accounting for air transportation. The driving determinant for this result was the high degree of emissions used by the greenhouses in the Netherlands, as they are ponderously reliant on fossil fuels. The greenhouses in Kenya, on the other hand, use geothermal energy, resulting in a substantial reduction in emissions. As Williams (2007) pointed out, geothermal energy can significantly alter the dichotomous debate of whether to produce locally versus importing long-range. Despite the encompassing positive externalities, a marginal number of greenhouses currently run on geothermal energy. This paper will outline the symbiotic advantages and disadvantages of using geothermal energy to generate energy for greenhouses, ultimately analyzing the mitigation of risk, emissions reductions, and optimization of profitability when producing vegetables and fruits through the usage of geothermal energy in Germany. This research uses the case of Kirchweidach to illustrate respective characteristics.

The structure of the paper is as followed: The second section entails a short market analysis and assessment of the heating market and greenhouses in Germany. A SWOT analysis of both geothermal energy and greenhouses follows third. The key findings of the SWOT analyses are illustrated in the fourth section. Assembling the results and looking at the example of Kirchweidach in detail leads to the conclusion at the last section of the paper.

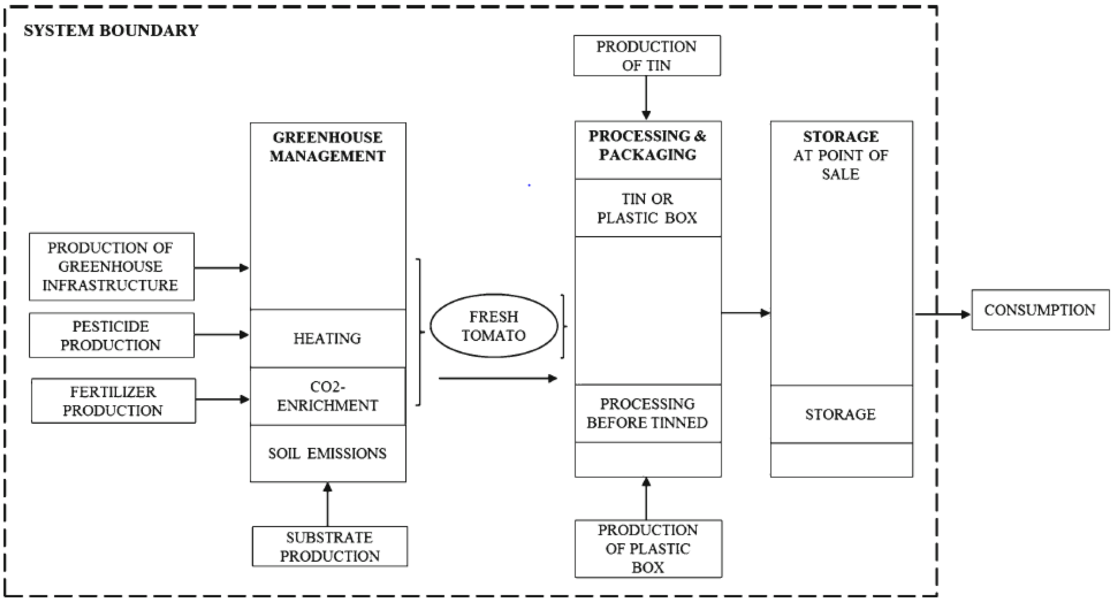

Figure 2: Emission cycle assessment of tomato production process. Source: Theurl et al. (2014)

2. MARKET ANALYSIS

2.1 Geothermal energy and energy market in Germany

As argued by Purkus and Bath (2011), the potential of geothermal energy is largely undeveloped. Paschen et al. (2003) and Purkus and Bath (2011) further argue that potentially geothermal energy could provide energy for approximately 50% of the electricity demand in Germany. Simultaneously, looking at the report published by the federal ministry for Economic Affairs and Energy (BMWi, 2018), the gross electricity generation of geothermal energy accounts for only 0.1 % (see: Figure 3). The German Renewable Energy Sources Act (EEG) subsidizes electricity from geothermal currently with 25.20 cents per kilowatt- hour over a period of 20 year after commissioning. If the commissioning falls in the years after 2020, the governmental support decreases by 5 percent per annum.

Besides the potential electricity production, the hot water can potentially supply the heating grids of nearby municipalities. In Germany, heating consumption composed of private household heating, commerce trade, and services heating & industry heating is responsible for 54% of the final energy consumption (KfW, 2016). Thus, to accomplish the projected energy goals, and successful transition in accord with the energy trajectories for 2020, heating remains an indispensable determinant. Although being responsible for more than 50 % of Germany’s yearly greenhouse gas emissions, the heating sectors remains in its infancy in terms of target formulation for the energy transition. Estimations of potential often return wide spectrums. TAB (2003) calculated geothermal energy uses of up to 700 TWh yearly for low enthalpy heating grids and around 240 TWh of heat derived from combined heat and electricity cycles. Recent analysis by UBA (2018) confirm the results, stating possible heat outputs of 279 TWh of heat yearly. Focusing on heating projects from geothermal can be very beneficial as it reduces the complexity of technological components and states smaller demands on flow temperature and flow rate. Thereby, more geothermal sources are suitable and can be implemented in the energy system.

Two seminal forces are reshaping the current landscape of Germany’s energy market: Firstly, changes in technology and secondly government intervention through subsidies and fees. Kirchweidach is a prime example of energy transformation implementation with governmental support, showing the feasibility of successful, forward-looking substitution of fossil fuels. A sizable part of the project was the creation of the district heating grid with a total length of 18 km. Contributing 2.07 million Euros the Kreditanstalt für Wiederaufbau (KfW) took a prominent financial role. The Landesförderinstitut des Freistaats Bayern (LfA) Förderbank in Bavaria supported these efforts contributing approximately 750,000 Euros. The regional district heating project enables the community of Kirchweidach to save approximately 1.32 million litres of fuel oil yearly and the vegetable farmer Steiner a further 4.8 million litres of fuel oil yearly (KiwE, 2015). Using yearly approximately 121 GWh_{th} in total, the geothermal energy source allows the municipality of Kirchweidach to save 38.6 million kg CO_2 emissions yearly. In 2016, the federal ministry for Economic Affairs and Energy invested 19.55 million Euro in research in 22 new deep geothermal energy projects, while supporting the subsistence of ongoing projects with 12.54 million Euro (BMWi, 2017).

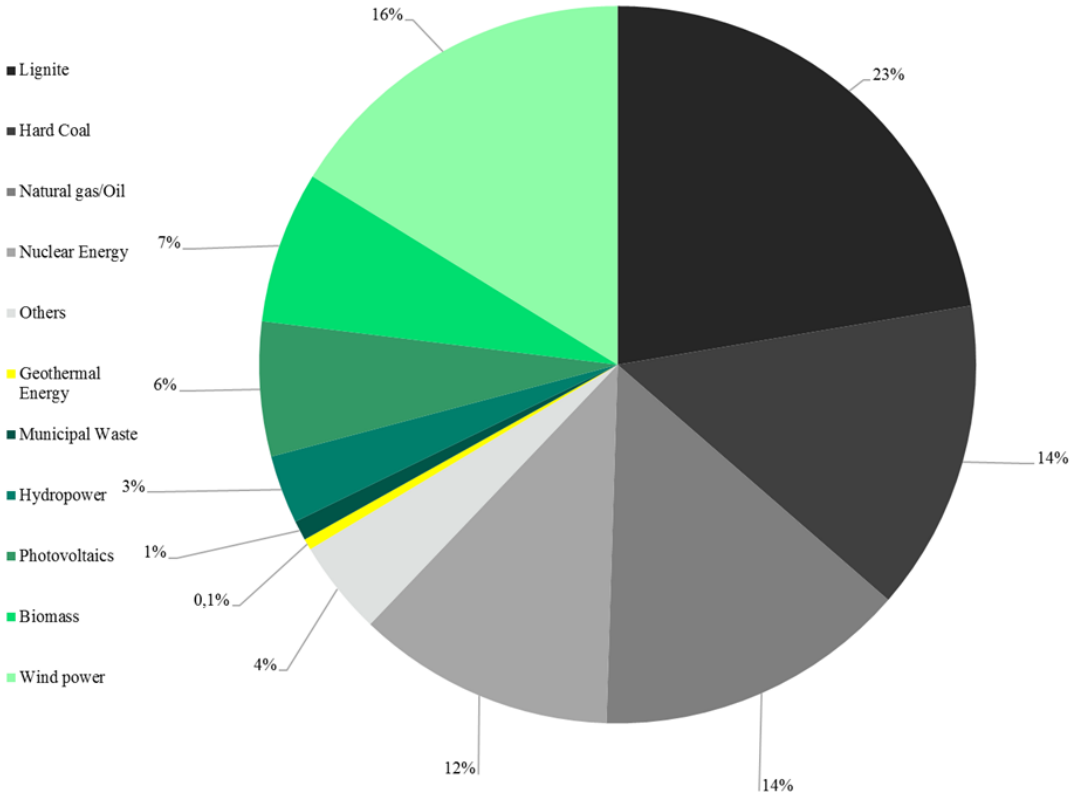

Figure 3: Gross electric generation in Germany in 2018 in percent, Source: BMWi (2018).

2.2 Greenhouses

Greenhouses have several advantages relative to open field production. Jones et al. (2016) point out that greenhouses bring benefits such as substantially higher yields, optimized water usage and diminished usage of chemicals. Irrespective, greenhouses' usage has faced a considerable share of criticism. Critics have pointed out that the heat-usage when employing greenhouses is not sustainable. To provide the amount of energy needed to power these greenhouses, a large share of fossil fuel is used. However, studies have pointed out that the sustainability of greenhouses is dependent on the surrounding environment of the greenhouse. The Netherlands has worse conditions compared to Spain. Due to the favorable climate and light, production in Spain can reduce costs and emissions. Labour and highly developed greenhouse production systems result in high cost structures (Cantliffe and Vansickle, 2003).

Scholars have pointed out that rather than greenhouses, consumption patterns have detrimental effects for our environment. Tomato consumption all over Europe has increased, enduring year around. To shelter more sophisticated consumer demands, production needs to accelerate in efficiency while simultaneously ensuring that the undertaken production is sustainable. The German greenhouse market operates on approximately 2,500 ha for the production of fruit and vegetables (BMEL, 2017). In comparison, the market in the Netherlands embraces over 6,000 ha (CBS, 2019). Greenhouses have been subject to disruptive innovation. There remains an undiscovered potential to accommodate the conundrum of requiring more products and having less space. An outlook on the future development entails an inevitable degree of uncertainty, but the possible applications range from the familiar huge glass construction on the ground, up to rooftops in urban areas as a part of urban gardening.

3. METHODOLOGY

This paper employs strength, weakness, opportunity and threat (SWOT) analysis. Numerous scholars studying sustainable and renewable energy have used SWOT analysis to outline respective determinants. SWOT analysis originates from business and marketing studies (Chen et al., 2014). Public Administration scholarship has adopted SWOT analysis in the 1980s, providing considerable success in the branch of energy (Markovska et al., 2009). Strategic conceptualization and project management use SWOT analysis frequently. As elucidated by Igliński et al. (2015) strengths and weaknesses examine internal, present advantages and disadvantages. They further argue that opportunities and threats examine the external, future consideration that stimulate or jeopardize further undertakings. These SWOT analyses were undertaken using information from recent business reports, information by the municipality, and recent empirical studies.

3.1 Geothermal energy

3.1.1 Positive aspects

There are numerous eminent positive characteristics of geothermal energy. **Regional value creation** is an internal externality of ample concern. The use of regional geothermal energy enables the community to support and reintegrate the regional economy.

Autonomous subsistence is a second internal strength. Not only is geothermal energy as such independent from changes in the weather (BMWi, 2017); the major advantage of this independence is that geothermal energy is suitable to cover the base load and gaps in the power supply. Given the base-load opportunity further saves expenses towards storage technologies. Geothermal energy also gives room to energy pricing mostly independent from turmoil in international financial and oil markets. Autonomy is pivotal for the sustenance of energy providers in the Germany energy market, given the current geopolitical situation in Germany.

Table 1 SWOT Profile- Geothermal energy

	Internal	External
Positive	*Strengths*	*Opportunities*
	Regional value creation	Public support
	Autonomous subsistence	Substitution
	Long-term planning security	Emissions fees
	Renewability	Emerging opportunities
	Efficiency	Competition
Negative	*Weaknesses*	*Threats*
	High initial investment cost	Image
	Long development period	Uncertainty
	Exploration risk	Insufficient governmental support
	Dependence on location	Competition

Energy dependence remains a crucial leverage-point, distorting the geopolitical landscape of the energy market. The financial crisis and the volatile dynamic in the oil market have made alternative sources of energy more attractive and increased the demand for **long-term planning security**. The recovery from the latest economic recession in 2008 shows that prices for fossil fuels are prone to rise. Thus, geothermal regional energy provision allows for more autonomy, ultimately resulting in more price stability.

The **renewable** character is an imperative strength of geothermal energy. Given that technically geothermal energy can sustain for an indefinite period and maintains the possibility of bearing baseload, geothermal energy is superior relative to other types of energy (Rödl & Partner, 2019), both fossil and renewable.

A further strength is the **efficiency** in large-size substitution of heating oil and natural gas. After completing the drilling, the plant is virtually invisible in size, but able to deploy heating energy for up to 15,000 households or 50 ha of greenhouses (Rödl & Partner, 2019).

When focusing on external positives, **public support** is one of the largest opportunities**.** After overcoming the first concern and including the public in all phases in the projects, public acknowledgement has been present at various projects, even culminating in pride of the local achievements. As stated by vegetable farmer Steiner, the project has stimulated local social engagement, due to the emphasis on communicating regional development (KiwE, 2015). Ultimately, the conscious usage of nature and resources further stimulates social engagement.

Substitution is one of the largest advantages, especially given the finite character of the current heating market. Geothermal energy allows for increased usage of renewable and sustainable energy practices. Most of the opportunities to derive geothermal heat remain unmarketable and not attractive to investors because of the high investment cost at the early stages. Despite the advantage of being a source of electricity, heat is an even bigger potential application of geothermal energy measured by looking at the mere share of available heat as opposed to the available electricity from geothermal energy.

Given the upcoming recalibration of the oil price and a potential tightening of facilitating legislative frameworks to catch up with the domestic energy trajectories, the **emission fees**, e.g. carbon tax, are highly discussed in politics and media and are prone to introduction in the predictable future (KfW, 2016). Upcoming fees potentially increase the total cost of fossil fuels, making renewable energy comparatively attractive.

The energy trajectories are creating a sizable share of new **emerging opportunities**. EEG is already making geothermal energy more attractive, building the pathway to granular recalibration in the energy market (BCG, 2013).

3.1.2 Negative aspects

Despite the obvious advantages of geothermal energy, there are numerous negative considerations, cost being one of the most disruptive considerations. As elucidated by Agemar et al. (2014), geothermal energy faces elevated financial risks due to the high initial **investment costs**. Especially given the fact that geothermal energy usage in Germany remains in its infancy, large developments fail to materialize. There is room for optimization and improvements at numerous levels of the supply chain.

Due to the size of the operation, especially in the first stages of the project, the time to commissioning can take up to three years. The **long development period** is a detrimental shortcoming of geothermal energy (Rödl & Partner, 2019). Geothermal energy requires a commitment beyond the duration of other energy sources that require briefer periods of construction.

Geothermal energy is available only at finite availability. **Location dependency** is a pernicious externality of internal nature. One of the pivotal stages to investing in geothermal energy is the stage of **exploration**. This stage requires sizable investments. Given the uncertainty about actually reaching fertile outcomes, most investments require insurance. These insurances are humongous financial commitments, diminishing the appeal of geothermal energy (Rödl & Partner, 2019).

Competition or more specifically the lack thereof, is a threat that scholarship points out repeatedly. The lack of sufficient competition in the industry, caused by the finite resource-availability and scarce number of contractors with the expertise and ambition to undertake a project of this landscape, markets fail to reach full potential. A lack of competition gives the few producers of geothermal energy a monopoly-like position in the market, leading to rapacious profit schemes, ultimately driving out market potential. Further optimization can increase the overall market position of geothermal energy but requires further supervision.

In a time dominated by social media and public interest, the **image** of geothermal is an important part of its recognition. Given the infancy of geothermal energy in Germany, any damage in image will have detrimental repercussion. Precision, caution, and safety are indispensable to the future success but also establishment of geothermal energy as a reliable source of sustainable energy. Undoubtedly, communicating these positive externalities is vital to positively shaping the image, while mitigating doubts and distrust remains a granular concern of the entire industry.

The long-term commitment, as required by geothermal energy, evokes a high level of risk involved for investors and therefore a high level of **uncertainty**. Given the rapid technological progress, competing sources of energy have a high probability to enjoy disruptive innovation, changing the landscape of renewables. Investors face the risk of committing to a lengthy investment inferior to competitors if given competitors substantial outperform the current industry. Further subsidies, investments in R&D, and fitted incentives are indispensable for the long-term profitability and subsistence of geothermal energy. Crucial here are government subsidies and more competition, forcing current geothermal energy providers to optimize their current operations.

As mentioned, **governmental support** is of considerable importance for the future of renewables and specifically geothermal energy (BCG, 2013; KfW, 2016). Geothermal energy remains highly regulated, only accessible to usage when the issuer accounts for sufficient qualification. On the one hand, the government has to make geothermal energy accessible for a larger share of consumers. The German governmental regulations and rules circumvent the wider spread of geothermal energy. Deliberate policies, steering towards the spread of geothermal energy on a wider scale are needed and the lack of deliberate policies might inhibit probable growth. In the political discussion, one point in particular has to stand out: mitigation of the exploitation risk. In the last few years, only countries with integrated security measures have made mentionable progress developing geothermal projects.

3.2 Greenhouses

Table 2 SWOT Profile- Greenhouses

	Internal	**External**
Positive	*Strengths*	*Opportunities*
	Agricultural potential and diversity	Technological progress
	Autonomy	Environmental sustainability
	Regional value creation	Public support
	Secure long-term planning	Social engagement
	Ecology of Scale	
Negative	*Weaknesses*	*Threats*
	Energy usage	Corroborate initial distrust
	Dependency on energy prices	Reluctance of investors
	Increasing fuel costs	Distrust
	Transport	Usage rate and Distribution

3.2.1 Positive aspects

Greenhouses provide fertile ground to optimize, maximizing **agricultural potential**. As pointed out by Jones et al. (2006), greenhouses are able to diminish water usage, usage of chemicals producing higher yields whilst increasing the diversity compared to open fields. Ultimately, space usage is more efficiently using greenhouses. Scarcity of space will increase in relevance, given the accelerating urbanization and densification of land space. Moreover, this potentially can result in cost efficient agricultural products.

A second vital positive externality is the **autonomy.** Greenhouses have a comparative advantage relative to vegetables and fruit produced on open fields (Jones et al., 2006). Greenhouses remain dependent on the embedded weather and climate, but enjoy greater autonomy relative to open field production.

An imperative positive consideration is the resulting **social engagement**. Geothermal energy distorts the dichotomous relationship between importing goods and producing goods domestically. Moreover, regional production restores the value for the nature and locally produced goods. Leading by example, the presence of greenhouses can trigger a recalibration of consumer values due to the revitalization of **localized value creation** (KiwE, 2015).

Greenhouses, oftentimes considerable in size, require **secure long-term planning.** Therefore, investments in greenhouses are suited for lengthy investments and contracts. Greenhouses require a consistent demand to accommodate production. Long-term contracts, efficient supply-chain-management- systems and stern cost structures facilitate the profitability of green houses, ultimately ensuring the sustenance in the long run.

Large-scale production allows for a wider spread of fixed costs over a larger quantity of cost, thus, resulting in cheaper production. The same holds for emissions. **Ecology of scale** refers to the derogation of emissions because of more efficient production (Edward-Jones et al., 2008). This occurs when, for instance, large truckloads transport goods compared to when scarce number of goods are transported an extensive distance. Large-scale greenhouses can marginalize and conclusively optimize the fixed cost of production.

An external consideration is the inevitable future **technological progress** will reduce the costs of greenhouses. Due to the amplified usage of greenhouse products and governmental pressure to meet energy trajectories, further demand for technological progress is inevitable, ultimately accelerating the profitability and accommodating the usage of potentially less pernicious greenhouses.

Currently, most greenhouses are using a substantial amount of energy, commodiously accompanied by using fossil fuels and hence emissions. Due to this unsustainably high degree of emissions, the public perception of greenhouses is negative in terms of sustainability. By substituting these fossil fuels, renewable energy provision enables greenhouse to reshape public perception and stimulate more support. By showing that greenhouses can be sustainable, a change in **public perception** can ultimately result in more regional economic activity. Usage of sustainable energy rather than fossil sources of energy accommodates long-term **sustainability**. In addition, submitting to local production is competitive and climate friendly at the same time, restoring the perception that locally produced goods entail positive externalities for local communities and leading to **social engagement** from and towards the greenhouses.

3.2.2 Negative aspects

One common perception of greenhouses is the unsustainability caused by their high**-energy usage.** Most greenhouses are fueled using fossil fuels. Substituting this energy usage with renewable or at least sustainable energy sources is pivotal, as the status quo remains one of the biggest shortcomings. Suboptimal conditions for farming the vegetable of concern reinforce these notions. For instance, the Netherlands produces many tomatoes but has significantly higher costs producing tomatoes because of the weather and the necessity of more sophisticated greenhouses to ensure production. Greenhouses in Spain, on the other hand, do not need the same degree of sophistication. The weather and climate in Spain are forthcoming for the production of tomatoes. The weather and climate in the Netherlands, on the other hand, tampers the production. Given the ecology of scale, current fruit and vegetable exporters operate at a high degree of efficiency.

Further, because of the **dependence** on fossil energy sources, frictions in energy prices heavily alter greenhouse profitability. Due to the high usage, small alterations cause ample change in costs for greenhouses. Concurrently, due to high usage, the **fuel costs** increase for greenhouses. Specialization and large-scale production, which benefit from economies of scale oftentimes, export their goods to a vast share of locations. This leads to humongous travel distances, accelerating **transportation costs**.

From the outside looking in, greenhouses have been prone to negative judgement frequently. Due to the currently indispensable need for fossil fuels, greenhouses oftentimes fail to produce without pernicious externalities. A failure of scandal is highly likely to corroborate this **initial distrust** of being ill fitted to provide sustainable goods.

Looking at the internal problems and the public's perception, **investors** may be **reluctant to make investments**. Long-term security is rudimentary for investors to invest in such business models. Planning of the **usage rate and distribution** is necessary to render certainty for food producers. Only if the anticipated returns of the investors are fulfilled, will obstacles be dismantled in the future.

4. DISCUSSION

Comparing both, geothermal energy and greenhouses have a substantial overlap in their SWOT analysis results. The merger between geothermal energy and greenhouses mitigates numerous risks of greenhouses. By creating long-term ties, greenhouses become increasingly autonomous, ensuring the subsistence in solitude of developments in the international energy markets for fossil fuels. Greenhouses can improve when given steady cost structure, marginalizing uncertainty. Geothermal energy is more autonomous than fossil fuels, therefore granting producers more certainty. Thorough planning and using geothermal energy moderated the risks of uncertainty and the dependency on energy markets. By involving business partners in early stages, reluctant tendencies and distrust disappeared. In the case of Kirchweidach, contracts with one of the biggest retailers in Germany ensure that demand accommodates the produced food. The greenhouse operator Steiner ensured that there is no mismatch between supply and demand, avoiding abundances and shortages of production. The location decision of Kirchweidach proved very beneficial for both business and environment. One can save 1.6 million kilometres of truck-mileage when importing from Spain and 400,000 kilometres of truck millage relative to imports from the Netherlands. Today, the production capacities fill regional demand of approximately 1 million citizens in Bavaria. Geothermal energy enables saving of 7.5 million m^3 natural gas and 14 million kg CO_2 emissions yearly relative to heating with natural gas. Given the high cost of transportation and high degrees of emission, the regional production allows for further optimization.

Furthermore, the partnership also benefits the geothermal project. Due to the high initial investment costs, planning stability is a significant component of geothermal energy projects. The current German legislation authorized feed-in tariffs of 25 cents per kilowatt-hour for geothermal electricity. Shifting the focus away from the electricity production calls for a long-term customer of considerable size. Thus, geothermal and greenhouses form an ideal combination. Both partners are interested in long-term contracts and security, concluding in price stability. Hence, exploration risks are alleviated and profits are achieved. The sustaining contracts lead to resilient business planning and interest from investors, eventually increasing the profitability of both projects (Rödl & Partner, 2015).

With possible electrical and heating generation, Kirchweidach constructed an innovative pricing system, simultaneously keeping the feed-in tariffs in mind. Figure 4 illustrates the conceptual model created for Kirchweidach. The pricing system consists of hourly opportunity costs for foregone electricity generation. The electrical power of a geothermal power plant depends on the flow rate and the ambient temperature. When heat is extracted to supply the district-heating system, the electrical power generation capacity diminishes. A seen in figure 4, the maximum electrical power without heat extraction at a certain ambient temperature is significantly higher compared to generating power and heat at the same time. The higher the heat extraction, the lower the possible electrical output. This drop-in electricity production leads to missing revenues. Thus, additional revenues from the district heating system must balance the forgone opportunity costs.

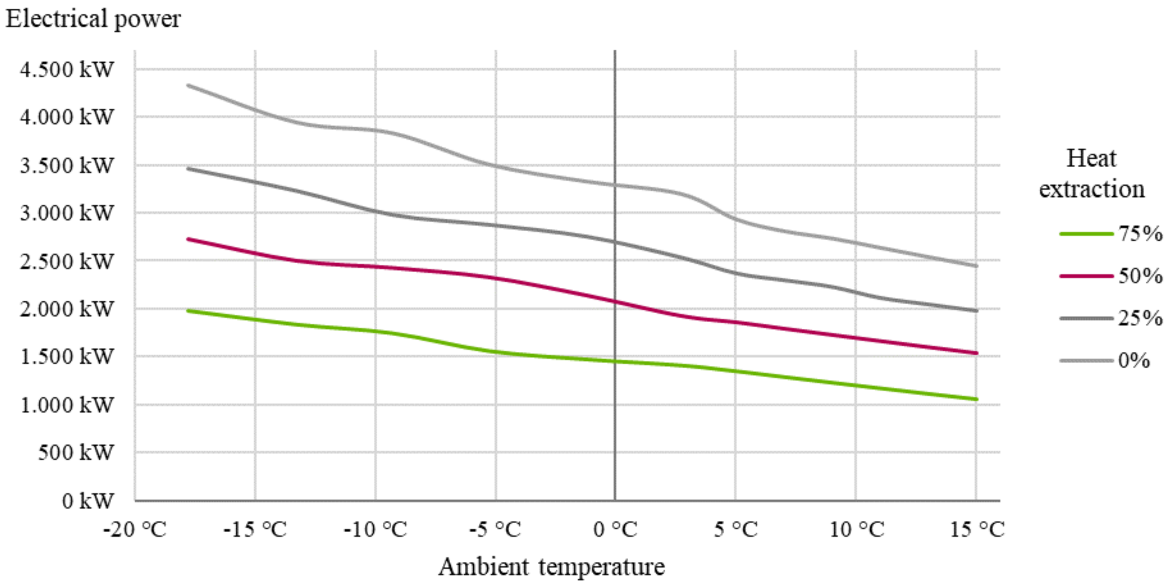

Figure 4: Hourly opportunity costs for foregone electricity generation. Source: (Rödl & Partner, 2015).

The symbiotic collaboration empowers the exploration of both regional energy potential and the regional agricultural potential, ultimately resulting in accelerated regional value creation. One of the main factors of the Kirchweidach examples embodies the open communication strategy. The involvement of the citizens proved crucial for internalizing negative externalities. Open discussions, information seminars, guided tours through the premises eliminated the initial distrust and helping shaping a positive image of geothermal energy and greenhouse farming. The presence of the district heating system has produced considerable public support, due to the visibility and tangible benefits for the citizens of the municipality. Despite the need to produce electricity to remain profitable, providing heat has altered public perception, resulting in a favorable verdict towards the implementation of geothermal energy. The district heating system was an indispensable component of geothermal energy implementation.

The support of the municipality, citizens and private investors at hand allowed for the utilization of opportunities. The social engagement finally translated into local value added. The project allowed for the creation of 150 new jobs, nearby companies carried out construction, the substitution of energy imports and reduction of emissions. Correspondingly, Kirchweidach received the Global District Energy Climate Award in the category "Special Award" in 2015.

The business model in Kirchweidach remains a beacon in the industry. By unleashing the unraveled potential, future projects can be underpinned, using this case as a prime example of successful and sustainable greenhouse production. Both, the successful public appearance of geothermal energy and greenhouse production stimulate positive overlapping synergies. Communication is pivotal to reshape the public perception and awareness, awareness being an imperative objective given the infancy of geothermal energy usage in Germany and beyond the borders.

5. CONCLUSION

Long-term profitability is one of the most important key words for further energy providers. Geothermal energy allows for renewable forward-looking heat and electricity with wide applicability. Electricity derived from geothermal energy sources are prone to further application in a vast share of sectors. Geothermal energy holds the potential to reshape the public perception of electricity-dependent undertakings significantly.

While geothermal energy is mainly used to derive electricity, geothermal energy has a lot of unexploited capacities to provide heat. Theurl et al. (2014) argue that heating has major potential to diminish pollution, especially given the fact that emissions for heating are higher than emissions for long distance road transport and energy intensive processing and packaging. One should point out the difference between geothermal reserves and resources. Resources are reserves that are considered profitable, therefore of economic use. Geothermal energy has a lot more reserves than they have resources because of costly early stage investments. Locations with the opportunity to derive electricity are preferred over locations with heat below the necessary threshold to derive electricity. Once technological progress makes geothermal energy more accessible and the focus in energy politics shifts towards transitioning the heating sector, exponential growth in geothermal heating is possible.

Governmental actors remain an inalienable component of the recalibration-process of the German heating sector. Research by the KfW (2016) points out that heating takes a vital role in accommodating the renewable energy trajectories. Fitted government policies hold the potential to reshape the granular outlook of the sector, and require considerable attention and caution. BCG (2013) underpins that a large degree of the development in the energy sector is dependent on regulatory frameworks and government intervention. Ultimately, both the government and technological developments can unleash opportunities for renewable, sustainable energy and specifically geothermal energy. These detrimental forces facilitate the pathway to the current trajectories for the German energy market.

The discussion showed that geothermal energy and greenhouses have symbiotic overlays that mitigate each other's risks. Most importantly, the profitability of both projects rises, creating a win-win-situation. On the example of Kirchweidach and vegetable farmer Steiner pivotal success factors were identified: **social engagement and acceptance, innovative pricing system long-term contracts, and local value creation**.

By involving the inhabitants in all project-phases, informing about used technologies and about required steps throughout, the citizens were educated about the specifications of the project starting from the early stages. One main factor for gathering acceptance was the on-hand use of heating their own houses with geothermal energy, thereby saving fossil fuels and saving the nature.

The innovative heating price system is based on an opportunity cost approach. To determine the heating price, the price system takes foregone electricity sales for feed-in tariffs under the German Renewables Act into account. The price-formula entails the ambient temperature, flow rates and rated power of the plant. The calculation of the heating price is undertaken hourly to maximize precision. The pricing system acknowledges the heat supply and allows the geothermal plant to be heat-operated whilst simultaneously operating at a profitable level using the opportunity cost approach.

One major disadvantage of both geothermal and greenhouse projects is the high initial investment cost. By signing long-term contracts, steady and plannable money flows ensure profitable operation. Pairing greenhouses with geothermal, energy demand and energy supply respectively is met and creates a win-win situation for both partners. Further, collaboration with REWE generates secure purchases and distribution for the entire production.

Bringing such a sizable project to a small town comes with effort and a certain amount of risk. The example Kirchweidach shows the upside and value added for the local and federal region. Firstly, constructors are paid, new jobs are created and the business taxes remains in the municipality, leading to higher spending in the region and wealth (KiwE, 2015). Secondly, the expenses for energy stay in the region and does not leave the value chain. Thirdly, vegetable production, distribution and consumption rise in the region, resulting in less emissions and a reduction in prices at the same time.

Summarizing, the analysis and the beacon in Kirchweidach lead to the conclusion that geothermal projects with greenhouses as their main energy costumers is a sustainable, future-looking combination. With the transformation of the heating sector coming alive in the next decade, higher demands of locally produced and affordable groceries and overall reduction of emissions, impediments will reduce, making projects more profitable and interesting for investors.

On an EU-scale, heat-driven projects can build up a portfolio of successful examples, if politics and decision-makers act accordingly. Possibilities are manifold: from huge greenhouses in the countryside to rooftop greenhouses in dense areas. Moreover, the European Commission (2016) stated that 25% of the European population lives in regions suitable for geothermal district heating application. Now is the time to rise to the occasion and be on the frontline of innovative projects.

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Appendix Table A

Abbreviations	**Label**
BCG	The Boston Consulting Group
BMWi	Federal Ministry for Economic Affairs and Energy
CH_4,	Methane
CO_2	Carbon dioxide
GWh	Gigawatt hour
GWh_{th}	Gigawatt-hours thermal
IGD	Institute of Grocery Distribution
KfW	Credit Institute for Reconstruction
LfA	Landesförderinstitut des Freistaats Bayern
N_2O	Nitrous oxide
R&D	Research and Development
TWh	Terawatt hour