Theoretical case study I:

ESG project in Upper Austria

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DOCUMENT CONTROL

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1. GEOTHERMAL ENERGY IN AUSTRIA

1.1. Technological and Strategic Developments

Geothermal energy has a long history in Austria, but its current use is relatively underdeveloped compared to other renewable energy sources. Despite its considerable potential, geothermal energy contributes only 1.6% to Austria's renewable heat production and an almost negligible amount to electricity generation (Goldbrunner and Goetzl, 2019). However, this is beginning to change as Austria recognises the importance of geothermal energy in achieving its climate goals, particularly the target of climate neutrality by 2040.

Geothermal energy is mainly used for heating, with a strong focus on both deep geothermal applications and shallow geothermal systems such as ground source heat pumps. There are currently more than 100,000 geothermal heat pump units in operation throughout the country, generating a total of about 2.3 TWh of heat per year (Energy Innovation Austria, 2024). These systems are mainly used for individual heating and small-scale applications, reflecting the relatively decentralised nature of the Austrian geothermal sector.

In addition, Austria has ten operational geothermal plants that make direct use of naturally occurring thermal water. These plants produce about 300 GWh of heat per year and contribute to district heating networks in several regions. While the use of geothermal energy for electricity generation is still limited, with only two sites producing around 2.5 GWh per year, there is growing interest in expanding this capacity, particularly through combined heat and power (CHP) plants (Energy Innovation Austria, 2024).

Austria is actively investing in research and development to unlock the full potential of geothermal energy. Key initiatives focus on both shallow and deep geothermal systems, exploring their ability to contribute to Austria's energy transition. Near-surface geothermal energy involves the use of borehole heat exchangers and heat pumps to extract heat from the uppermost layers of earth and rock, typically to depths of around 400 metres. This technology is particularly suitable for heating and cooling buildings and small communities. Deep geothermal energy, on the other hand, involves tapping heat resources at depths of 1,500 to 5,000 metres (Garabetian and Dumas, 201ti). At these depths, temperatures can exceed 60°C, making it possible to generate both heat and electricity. Austria's deep geothermal potential is being explored through projects such as GeoTief, which is mapping the deep subsurface in regions such as the Vienna Basin to identify viable geothermal resources for large-scale energy production (Energy Innovation Austria, 2024).

One of the most important aspects of Austria's geothermal strategy is the integration of geothermal energy into district heating networks. District heating accounts for a significant portion of Austria's energy consumption, and the transition of this sector to renewable energy sources is critical to achieving the country's climate goals. Geothermal energy is seen as a key component of this transition, providing a stable and sustainable heat source that can complement other renewable energy sources such as biomass and solar thermal.

1.2. Prospects, Economic Impact, and Strategic Considerations

Austria's geothermal sector is poised for significant growth. Studies suggest that near-surface geothermal energy alone could generate up to 15 TWh of heat per year by 2040, while deep geothermal systems could contribute an additional 9.2 TWh (Goldbrunner and Goetzl, 2019). In addition, there is a potential to produce 0.7 TWh of electricity from geothermal CHP plants, which would further diversify Austria's renewable energy por‘olio.

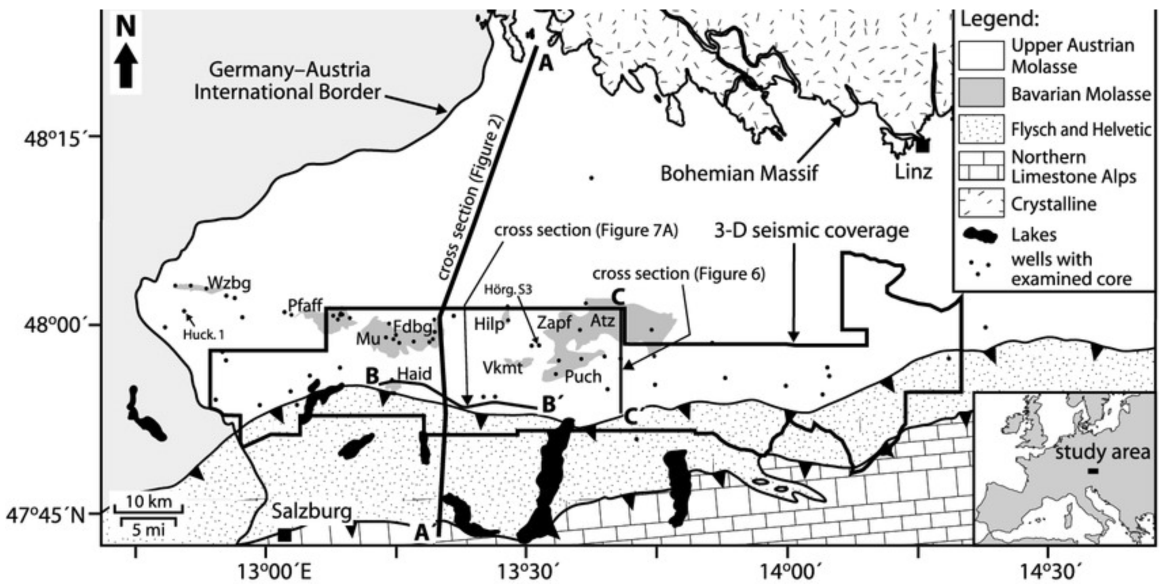
The development of geothermal energy in Austria is not only a maaer of environmental sustainability, but also of economic opportunity. A study by the Energy Institute of the Johannes Kepler University Linz estimates that the expansion of geothermal energy could create more than 12,000 new jobs by 2030, mainly in the areas of drilling, system installation and maintenance (Energy Innovation Austria, 2021). In addition, this expansion could contribute an extra €0.9 billion to Austria's GDP, underlining the economic benefits of investing in renewable energy technologies.

Despite its potential, the development of geothermal energy in Austria faces several challenges. One of the main obstacles is the high up-front costs associated with geothermal projects, especially deep geothermal systems, which require significant investment in drilling and infrastructure. There are also geological risks, as not all exploratory drilling will necessarily lead to successful geothermal wells. To mitigate these risks and encourage investment, Austria is exploring various policy measures, including feed-in tariffs for geothermal electricity and subsidies for geothermal heating systems.

2. THE MOLASSE BASIN: A KEY GEOTHERMAL RESOURCE IN UPPER AUSTRIA

Among Austria's geothermal regions, the Molasse Basin, particularly in Upper Austria, is one of the most important areas for geothermal energy development. This basin is an elongated sedimentary region that extends along the northern edge of the Alps across Austria, Germany, and Switzerland. The geological characteristics of the Molasse Basin make it particularly suitable for geothermal applications, mainly due to its favourable heat flow characteristics and extensive aquifer systems.

Figure 1: Map of the Molasse Basin in Upper Austria



Source: de Ruig and Hubbard (2008)

The Molasse Basin benefits from enhanced heat flow densities due to hydrodynamic convection processes. This enhanced heat flow is most pronounced in the Upper Jurassic Malm formations, which are widespread throughout the basin. These formations are composed of carbonate rocks with high permeability, allowing considerable groundwater flow. The low mineralisation of the water in these reservoirs makes them highly suitable for both direct heat applications and as a source of geothermal energy for electricity generation.

The geothermal potential of the Molasse Basin is particularly strong in its northern regions, where extensive geothermal exploration and development has already taken place. Several successful geothermal projects have been established to exploit the region's abundant geothermal resources. These projects have demonstrated the viability of using geothermal energy for district heating and other direct heat applications.

Despite these successes, the southern part of the Molasse Basin in Upper Austria remains largely underdeveloped. This area has significant untapped potential, particularly for the expansion of geothermal applications. The southern Molasse Basin offers opportunities for further exploration and development, which could significantly increase Austria's geothermal energy capacity. The development of geothermal resources in this region could play a key role in supporting Austria's transition to renewable energy, particularly in meeting the growing demand for sustainable heating solutions.

2.1. Geothermal Poten-al Near Ried im Innkreis, Upper Austria

The geothermal resources of the Molasse Basin in Upper Austria offer a particularly promising opportunity for the development of district heating networks, which are essential for the creation of sustainable urban energy systems (Goldbrunner, 2020). In the region around Ried im Innkreis, Upper Austria, the potential for the development of geothermal district heating networks is particularly high. The area has already made significant use of its geothermal resources, through the Ried-Mehrnbach geothermal project. This project taps into the high-temperature geothermal resources of the Upper Jurassic Malm aquifer, a geological formation known for its favourable fracture permeability and considerable geothermal potential.

The geothermal potential in this region is further enhanced by the presence of deep-seated fault systems, which facilitate the circulation of hot groundwater. These geological structures allow for the extraction of geothermal fluids at temperatures suitable not only for district heating but also for electricity generation. The successful drilling of the Mehrnbach Th 3 well, which encountered a 200-meter-thick dolomitic sequence, underscores the region's capacity to support large-scale geothermal developments. The well has been designed to deliver a flow volume of 100 litres per second during long-term pumping and reinjection tests, demonstrating the area's robust geothermal potential.

Figure 1: Map of the Molasse Basin in Upper Austria, cantered around the Ried-Mehrnbach plant

Source: Google Maps (2024)

The Ried-Mehrnbach geothermal plant, which is currently operational, taps into a geothermal reservoir at depths of more than 2,500 metres. Temperatures reach up to 105°C, making it an ideal source for district heating. The geothermal fluid extracted from this reservoir is used to supply heat to a district heating network that serves not only the town of Ried im Innkreis, but also the neighbouring village of Mehrnbach. The success of this project has proven the economic and technical feasibility of geothermal district heating in this region and there are already plans to further expand the capacity of the geothermal plant to meet the growing demand for sustainable heating.

The planned expansion of the Ried-Mehrnbach project is expected to significantly increase the installed geothermal capacity in Upper Austria. Current projections suggest that the capacity could be increased to around 19 MWth, which would make a significant contribution to the region's energy security and further consolidate Austria's position as a leader in the use of renewable energy. This expansion is in line with Austria's broader objectives of reducing greenhouse gas emissions and moving towards a more sustainable energy system.

In addition to its suitability for district heating, the geothermal resources near Ried im Innkreis offer promising opportunities for other industrial applications. For instance, the high-temperature geothermal fluid could be used to maintain optimal growing conditions in greenhouses, thereby supporting local agricultural industries. The integration of geothermal energy into such industrial processes not only enhances the economic viability of these operations but also contributes to reducing their carbon footprint, in line with Austria's environmental goals. Moreover, the expansion of geothermal energy use in this region could serve as a model for similar projects across Austria, showcasing the potential of geothermal energy to contribute to the country's renewable energy targets. The combination of favourable geological conditions, existing infrastructure, and the proven success of ongoing projects positions the Molasse Basin, particularly near Ried im Innkreis, as a key area for future geothermal energy development.

3. ENHANCED GEOTHERMAL SYSTEMS (EGS) PROJECT IN UPPER AUSTRIA

Building on Austria's growing recognition of geothermal energy as an important component of its renewable energy strategy, the development of Enhanced Geothermal Systems (EGS) represents a significant leap forward in harnessing the Earth's heat for sustainable energy production. The Molasse Basin, in particular the area around Ried im Innkreis in Upper Austria, offers an ideal geological environment for such an advanced project. This section describes the proposed EGS project in detail, outlining its strategic importance, technical specifications, and its potential to contribute to Austria's energy and environmental goals.

3.1. Strategic Importance of EGS in Austria's Energy Landscape

As Austria accelerates its efforts to achieve climate neutrality by 2040, the integration of cumngedge technologies such as Enhanced Geothermal Systems is crucial. Traditional geothermal methods, while effective, are limited by the availability of naturally occurring hydrothermal reservoirs. EGS technology, however, overcomes these limitations by creating artificial geothermal reservoirs, allowing geothermal energy to be extracted in regions previously considered unsuitable for such operations.

The proposed EGS project in Ried im Innkreis is strategically important for several reasons:

- **Resource Op1miza1on:** By leveraging the EGS approach, the project can tap into deep geothermal resources that would otherwise remain inaccessible, thus maximizing the energy potential of the Molasse Basin.
- **Energy Security:** The project will provide a stable, year-round supply of both electricity and thermal energy, contributing to the diversification and resilience of Austria’s energy grid.
- **Environmental Impact:** EGS technology allows for a substantial reduction in greenhouse gas emissions compared to fossil fuel-based energy production, aligning perfectly with Austria’s environmental and climate targets.
- **Economic Development:** The project is expected to stimulate local economies by creating jobs and fostering the development of specialized skills in geothermal technology, while also aaracting further investments in renewable energy.

3.2. Technical Specifications and Justifications

The design and implementation of the EGS project are rooted in detailed geological surveys and advanced engineering practices, ensuring that the project is both technically feasible and economically viable. Below are the key technical specifications and the rationale behind each decision:

Location: Near Ried im Innkreis, Upper Austria

The selected location within the Molasse Basin is known for its favourable geological conditions, including high permeability and elevated heat flow densities, making it an ideal site for an EGS project. The success of existing geothermal projects in this region further supports the choice of location.

Reservoir Type: Enhanced Geothermal System (EGS)

EGS technology is essential for extracting geothermal energy from areas lacking sufficient natural hydrothermal resources. By artificially stimulating the subsurface, EGS enables the creation of a sustainable geothermal reservoir, making it a transformative technology for regions like Upper Austria.

Geology: Molasse Basin

The geological characteristics of the Molasse Basin, including its thick sedimentary layers and favorable thermal gradients, provide an optimal environment for the deployment of EGS. The basin's extensive aquifer systems further enhance the feasibility of maintaining high flow rates necessary for energy production.

Depth: 4,500 meters

Drilling to a depth of 4,500 meters is required to access the high temperatures necessary for efficient geothermal energy production. At this depth, the expected temperature of 165°C is ideal for driving the Organic Rankine Cycle (ORC) binary power plant, ensuring high efficiency and reliable energy output.

Temperature at Depth: 165°C

The temperature of 165°C at the target depth is optimal for the ORC system, allowing for the effective generation of electricity and the supply of thermal energy for district heating. This temperature range is based on geothermal gradient studies in the region, ensuring that the project can achieve its energy production goals.

Number of Wells: 2 (1 production well, 1 injection well)

A double-well configuration is chosen to maintain reservoir pressure and ensure the long-term sustainability of the geothermal system. The injection well reintroduces the cooled water back into the reservoir, which is critical for maintaining the balance and longevity of the geothermal resource.

Flow Rate: 60 litres per second

The flow rate of 60 litres per second has been calculated to optimize the thermal energy extraction from the reservoir while maintaining the integrity of the subsurface structures. This flow rate is sufficient to support the continuous operation of the ORC power plant, providing a steady output of both electricity and heat.

Power Plant Type: Binary Cycle (Organic Rankine Cycle - ORC)

The ORC binary cycle is the most suitable technology for moderate-temperature geothermal resources like those expected at the Ried im Innkreis site. It allows for the efficient conversion of geothermal heat into electricity, with the added benefit of operating in a closed-loop system that minimizes environmental impact.

Cooling System: Air-cooled condenser

The use of an air-cooled condenser aligns with the project's commitment to environmental sustainability by reducing water usage. This is particularly important in regions where water resources are limited, and it ensures that the project's operations are in line with Austria's environmental regulations.

Parasitic Load: 20%

The parasitic load, which represents the energy consumed by the plant's internal systems, is estimated at 20%. This figure reflects the energy demands of the ORC system, including pumping and cooling operations, and is within the typical range for geothermal plants of this type.

Net Capacity Factor: 90%

A net capacity factor of 90% indicates that the plant will operate near its maximum capacity for most of the year, ensuring a high return on investment and a reliable energy supply. This highcapacity factor is achievable due to the consistent nature of geothermal energy, which is not subject to the intermiaency issues that affect other renewable sources like wind and solar.

Projected Capacity: 5 MWe (electricity) + 40 MWth (thermal energy)

The projected output of 5 MWe and 40 MWth is based on the flow rate, temperature, and the efficiency of the ORC system. This dual-output approach maximizes the utility of the geothermal resource, providing both electricity for the grid and heat for district heating networks, thus contributing to the region's energy security and sustainability.

Project Lifetime: 30 years

The project is designed to operate for 30 years, a standard lifespan for geothermal projects. This duration reflects the durability of the infrastructure and the sustainable management of the geothermal resource, ensuring long-term energy production and economic benefits.

Table 1 summarises these factors and some characteristics of the resulting EGS project. The annual electricity production was calculated based on the nominal capacity of the plant (5,000 kWel), the net capacity factor (90%) and the number of operating hours per year (8,760 hours). The CO2 emissions avoided were calculated based on the expected annual electricity production and the carbon intensity of conventional electricity generation, assuming an average emission factor of 450 grams of CO_2 per kWh for fossil fuel-based electricity. Finally, the number of households served was estimated based on the expected annual electricity production and the average annual electricity consumption per household in Austria, which is approximately 3,600 kWh.

Table 1: Feature of the sample project

Location	Near Ried im Innkreis, Upper Austria
Geothermal gradient in °C/100m	3.3
Flow rate in l/s	60
Delivery temperature in °C	165
Temperature after power plant process in °C	60
Number of wells	2 (1 production, 1 injection)
Drilling depth per well in m	4,500
Geothermal nominal capacity in kWth	26,250
Electricity generation nominal capacity in kWel	5,000
Degree of efficiency	1ti%
Power plant type	Binary (ORC)
Cooling system	Air-cooled condenser
Parasitic load	20%
Net capacity factor	90%
Project lifetime in years	30
Reservoir type	Enhanced Geothermal System (EGS)
Geology	Molasse Basin
Stimulation method	Hydraulic stimulation
Expected annual electricity production in MWh	3ti,420
CO_2 emissions avoided per year (tons)	17,740
Number of households powered	Approximately 11,000

Source: simulated data (2024)

3.3. Evolution of project over time: costs and revenues

Table 2 shows the detailed investment breakdown for the model Enhanced Geothermal System (EGS) project in Austria. Spread over four years, the table details the financial commitments required for each critical phase of the project, from preparatory agreements to power plant construction, to ensure successful and sustainable geothermal development.

Table 2: Investment Overview of the Sample EGS Project in Austria

Item	Year 1	Year 2	Year 3	Year 4	Total
Seismic / preparatory arrangements	1,200,000	0	0	0	1,200,000
Land, drilling site	0	1,800,000	0	0	1,800,000
Wells, reservoir stimulation	0	0	32,000,000	0	32,000,000
Discovery and builders risk insurance	0	0	5,000,000	0	5,000,000
Delivery, injecting pumps	0	0	0	1,500,000	1,500,000
Power plant	0	0	0	15,000,000	15,000,000
Grid connection	0	0	0	800,000	800,000
Planning, consulting, project management	600,000	600,000	600,000	600,000	1,800,000
SUM	1,200,000	2,400,000	37,600,000	17,ti00,000	5ti,100,000

Source: simulated data (2024)

- **Seismic / Preparatory Arrangements (€1,200,000 in Year 1):** In the initial year, €1,200,000 is allocated for seismic surveys and preparatory work. These efforts are crucial for mapping the underground geology, ensuring accurate drilling and reservoir stimulation plans. Early investments in these activities mitigate risks and set a solid foundation for subsequent project phases.

- **Land, Drilling Site (€1,800,000 in Year 2):** Year 2 sees a significant investment in securing the necessary land and preparing the drilling site. The €1,800,000 budget covers land acquisition and infrastructure development, such as access roads and utilities, which are essential for supporting heavy drilling equipment and ensuring operational readiness.

- **Wells, Reservoir S1mula1on (€32,000,000 in Year 3):** The most substantial expenditure occurs in Year 3, with €32,000,000 dedicated to drilling wells and stimulating the geothermal reservoir. This phase involves deep drilling to access the geothermal resource and hydraulic stimulation to enhance fluid flow, which are critical to the project's energy output.

- **Discovery and Builders Risk Insurance (€5,000,000 in Year 3):** Simultaneously in Year 3, €5,000,000 is allocated for insurance coverage. This insurance protects the project against potential risks during drilling and construction, such as unforeseen geological challenges, ensuring financial stability and continuity of operations.

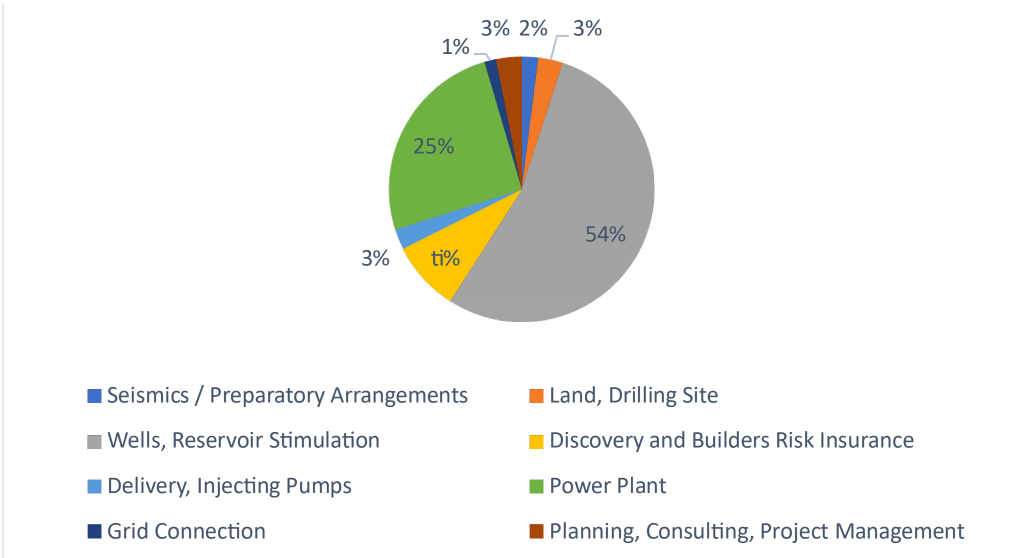
- **Delivery, Injec1ng Pumps (€1,500,000 in Year 4):** In Year 4, €1,500,000 is invested in the acquisition and installation of delivery and injecting pumps. These pumps are integral to maintaining the necessary fluid circulation between wells, directly impacting the efficiency and sustainability of the geothermal system.

- **Power Plant (€15,000,000 in Year 4):** The construction of the power plant is the key focus of Year 4, with €15,000,000 allocated. This investment includes building the ORC (Organic Rankine Cycle) system, which will convert geothermal energy into electricity, representing the project's central energy generation component.

- **Grid Connec1on (€800,000 in Year 4):** Also in Year 4, €800,000 is allocated for connecting the power plant to the national grid. This phase involves constructing the necessary electrical infrastructure to ensure that the generated electricity can be efficiently transmiaed and sold to the grid.

- **Planning, Consul1ng, Project Management (€600,000 per year, totaling €1,800,000):** Throughout all four years, a consistent annual investment of €600,000 is dedicated to planning, consulting, and project management. This ongoing investment ensures that the project is expertly managed, adhering to timelines, budgets, and regulatory requirements, ultimately guiding the project to successful completion.

Figure 3 : The apportionment of the investments of the sample EGS project



Source: simulated data (2024)

The total investment of EUR 59.1 million reflects the capital-intensive nature of deep geothermal projects, especially in areas without a long history of geothermal development. **Figure 3** shows the distribution of costs by investment category. The significant investment is primarily due to the challenging drilling conditions in the Molasse Basin, where reaching the target depth of 4,500 metres requires advanced drilling technologies and techniques. The geological complexity requires extensive reservoir stimulation to create an effective heat exchanger in the low permeability crystalline basement rocks, further increasing costs.

The project's investment breakdown, with 54.1% allocated to drilling and reservoir stimulation, underlines the critical importance of subsurface development. This high proportion is justified by the need for two deep wells (production and injection) and the sophisticated stimulation techniques required to enhance reservoir permeability. The significant investment in these components is critical to achieving the targeted flow rate of 60 litres per second at 165°C, which is essential for the economic viability of the project.

The power plant's 25.4% share of the total investment reflects the use of advanced Organic Rankine Cycle (ORC) technology optimised for the medium temperature resource characteristic of this part of Austria. This substantial allocation is justified by the need for highly efficient heat to power conversion to maximise the output from the available thermal resource, which is critical to the long-term economic success of the project.

The 8.5% allocated to exploration and construction risk insurance reflects the high-risk nature of geothermal development, particularly in a region where deep geothermal projects are not yet commonplace. These significant insurance costs are necessary to mitigate the significant geological and technical risks inherent in EGS projects, making the investment more palatable to equity investors and potential lenders.

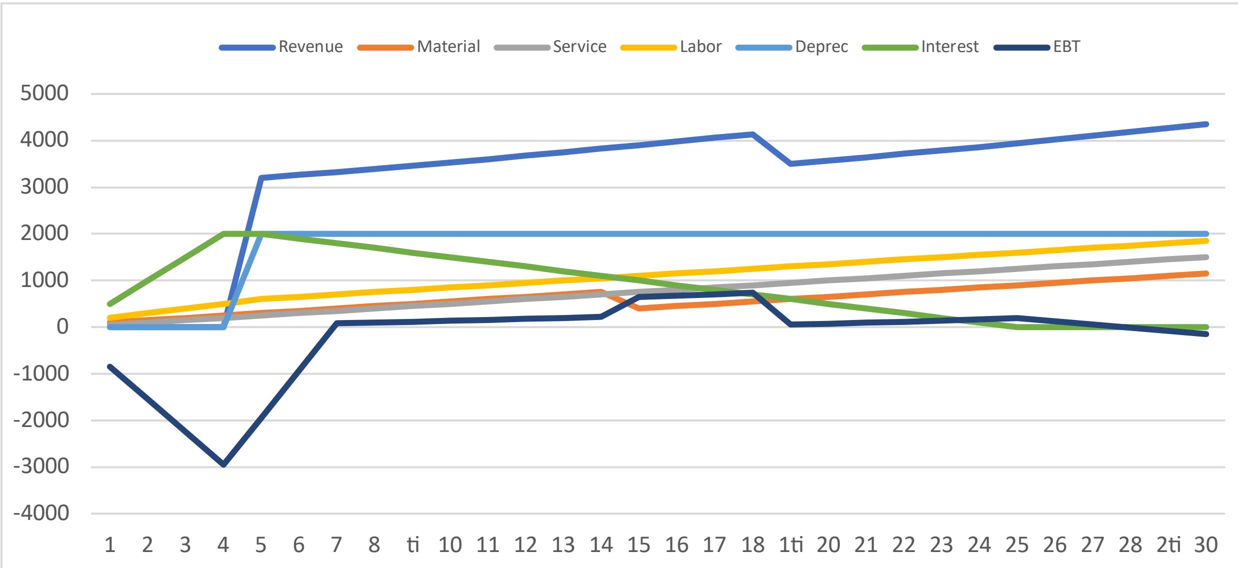
The financing structure of 67% equity and 33% debt is heavily weighted towards equity due to the high-risk profile of the early stages of geothermal development. This structure is necessitated by the reluctance of traditional lenders to provide debt financing until the resource has been proven through successful drilling and long-term flow testing. The higher equity requirement reflects the risk appetite for geothermal development in Austria, where the geothermal sector is less mature than other renewable energy technologies.

The reliance on equity financing in the early stages reflects the reality of geothermal development worldwide but is particularly pronounced in the Austrian context. The country's renewable energy sector has historically been dominated by hydropower and, more recently, wind and solar. Geothermal energy, especially for electricity generation, is a relatively new entrant in the Austrian renewable energy mix. This newness contributes to a higher perceived risk among traditional financiers, requiring a greater reliance on risk-tolerant equity investors.

The financial projections of the project are anchored in the Austrian renewable energy policy framework. The assumed feed-in tariff of EUR 72.5/MWh, derived as an expected value based on past years, provides a stable revenue base for the first 13 years of operation. While this guaranteed price is lower than some other renewable technologies, it reflects the baseload nature of geothermal power and its potential contribution to grid stability.

The conservative assumption of a 2% annual increase in electricity prices beyond the feed-in tariff period reflects Austria's gradual transition to a more market-oriented renewable energy sector. This modest growth projection recognises the uncertainties in long-term energy price trends, influenced by factors such as the increasing penetration of variable renewable sources (wind and solar) and potential changes in energy market structures.

Figure 4: Expenses and incomes of the EGS sample project



Source: simulated data (2024)

Figure 4 shows the evolution of incomes and expenses for the sample project.

Revenue Trajectory: Revenue generation for the EGS project begins in Year 5, with an initial income of €3,200,000 as the geothermal plant becomes operational. The early years of revenue are influenced heavily by the feed-in tariff, a government-supported incentive that guarantees a fixed price for the electricity generated. This tariff allows the project to benefit from a 2% annual increase in revenue, reflecting both the tariff's escalation and assumed inflation. However, this advantageous period concludes in Year 19, marking the end of the feed-in tariff. At this point, revenue drops to €3,500,000 as the project transitions to market prices. Despite this significant drop, revenue continues to grow at 2% annually in subsequent years, driven by projected market price increases. This revenue growth, however, is slower and reflects the uncertainties and competitive pressures of operating in the open market.

Material Costs: Material costs are relatively low during the initial years, aligning with the gradual ramp-up of operations. These costs, which include the purchase of materials necessary for the plant's maintenance and operation, increase steadily each year, reflecting both inflation and the growing maintenance needs as the facility ages. A notable decrease in material costs occurs in Year 15, when the project begins utilizing its self-generated electricity. This shift results in significant cost savings, as the project becomes less reliant on external electricity purchases. Following this decrease, material costs continue to rise modestly, driven by ongoing maintenance requirements and inflationary pressures.

Service Costs Dynamics: Service costs start low, as expected, given the newness of the plant and minimal maintenance needs. However, as the facility ages, these costs increase steadily, reflecting the rising demand for operational services, regular maintenance, and potential upgrades. The service costs are a critical component of the project's ongoing operational expenses, and their gradual increase underscores the importance of effective cost management strategies to maintain profitability.

Labour Costs Growth: Labour costs, representing the salaries and benefits of operational staff, start at €200,000 in Year 1. These costs grow annually, driven by inflation, the need to attract and retain skilled labour, and potential expansions in operational capacity. Labour costs are a consistent and growing expense throughout the project's life, reflecting the human resources required to operate and maintain the geothermal facility effectively.

Depreciation and Interest Expenses: Depreciation begins in Year 5, coinciding with the start of operations, and remains constant at €2,000,000 annually. This straight-line depreciation reflects the amortization of the initial investment over the project's useful life. Depreciation is a non-cash expense that significantly impacts the Earnings Before Tax (EBT), particularly in the early years. Interest expenses, on the other hand, start high at €500,000 in Year 1, as the project begins repaying the loan used to finance its construction. These expenses peak at €2,000,000 during Years 4 and 5, when the loan balance is at its highest. As the loan is gradually repaid, interest expenses decrease steadily, reaching zero by Year 25. The reduction in interest payments significantly improves the project's cash flow in the latter years.

Earnings Before Tax (EBT) Trends: EBT is negative in the initial years due to the high costs associated with construction and early operations, coupled with the lack of revenue. It turns positive in Year 7, when the revenue from electricity sales surpasses the operational costs. EBT peaks between Years 15 and 18, a period characterized by strong profitability driven by the combination of high revenue under the feed-in tariff and reduced material costs due to selfgenerated electricity use. However, the end of the feed-in tariff in Year 19 results in a sharp decline in EBT as the project transitions to market prices. Although the project remains profitable, EBT continues to decrease gradually in the later years as rising costs outpace the slower growth in revenue.

4. CONCLUSIONS

The sample EGS project in Upper Austria is an example of what could be a significant step forward in Austria's renewable energy strategy for the heating sector. The financial trajectory of the project, from initial investment to long-term revenue generation, illustrates both the opportunities and challenges associated with advanced geothermal energy systems.

Over the 30-year life of the project, a total investment of EUR 59.1 million is required, reflecting the capital-intensive nature of deep geothermal development. The majority of this investment - approximately 54.1% - is allocated to well drilling and reservoir stimulation. This significant allocation underlines the critical importance of subsurface development to the success of the project. Drilling to depths of 4,500 metres and using sophisticated stimulation techniques are essential to achieve the target flow rate of 60 litres per second at 165°C. These figures are critical to the economic viability of the project and have a direct impact on its ability to efficiently produce both electricity and thermal energy.

The ORC power plant represents 25.4% of the total investment. This significant proportion of the budget is justified by the need for a highly efficient heat-to-electricity conversion system, particularly given the medium temperature resource characteristic of the Molasse Basin. The ability of the ORC system to operate effectively in this temperature range is critical to maximising the output from the available thermal resource, which is central to the long-term success of the project.

Revenue generation starts in year 5, with an initial income of EUR 3.2 million as the geothermal plant becomes operational. The first few years of revenue are heavily influenced by the feed-in tariff, which guarantees a fixed price for the electricity generated. This tariff, which allows for a 2% annual increase in revenue, significantly enhances the financial stability of the project in its early stages. However, the expiry of the feed-in tariff in year 19 presents new challenges as the project transitions to market prices. Despite this, the projected revenue growth of 2% per annum in subsequent years suggests that the project can remain competitive, although this growth reflects the inherent uncertainties and competitive pressures of the open market.

An analysis of costs - including materials, services, labour, depreciation and interest - reveals a dynamic financial landscape. Material costs start low, reflecting the gradual ramp-up of operations, but rise steadily due to inflation and increasing maintenance requirements as the plant ages. There is a notable decrease in material costs in year 15, due to the project's use of self-generated electricity, which reduces reliance on external energy sources.

Service costs, which cover operational services and maintenance, follow a similar trajectory, increasing as the plant ages. Effective cost management will be essential to maintain profitability as these costs continue to rise. Labour costs, which include salaries and benefits for operational staff, increase annually due to inflation and the need to aaract and retain a skilled workforce. These costs remain constant throughout the life of the project, underlining the importance of efficient workforce management.

Depreciation and interest costs play a significant role in the financial health of the project, particularly in the early years. Depreciation remains constant at EUR 2 million per annum, reflecting the straight-line amortisation of the initial investment. This non-cash expense has a significant impact on EBT, particularly in the early years when revenues are still ramping up. The interest expense, which is initially high due to the financing structure, decreases steadily as the loan is repaid, reaching zero by year 25. This reduction in interest payments significantly improves the project's cash flow in later years, providing greater financial flexibility.

The EBT trend illustrates the project's progression from initial losses to eventual profitability. EBT is negative in the early years due to the high upfront costs and lack of revenue. However, it turns positive in year 7 as revenue from electricity sales begins to exceed operating costs. EBT peaks between years 15 and 18, driven by strong profitability under the feed-in tariff and reduced material costs from self-generated electricity. The end of the feed-in tariff in year 19 marks a turning point, leading to a sharp decline in EBT as the project adjusts to market prices. Despite this decline, the project remains profitable, although the margin is narrowing as costs rise and revenue growth slows.

In summary, the Upper Austria EGS project demonstrates the potential for geothermal energy to make a significant contribution to Austria's renewable energy future. The financial analysis underlines the importance of strategic planning, effective cost management and a clear understanding of market dynamics. While challenges exist, particularly in the transition from subsidised tariffs to market prices, the overall trajectory suggests that with careful management, the EGS project can deliver sustainable economic and environmental benefits over its 30-year lifetime.

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