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A Technoeconomic, Policy, and Regulation Assessment of an Integrated Campus Geothermal Energy System

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ABSTRACT

As part of the Department of Energy's Geothermal Collegiate Competition, the policy team developed a technoeconomic feasibility study of a geothermal energy system at the RELLIS campus of the Texas A&M University System, and developed the policy, regulatory and funding narrative to potentially build it. This paper and presentation will describe a geothermal energy system, centered around reusing current hydrocarbon wells on the campus and expanding their capabilities with additional boreholes, integrated into a campus wide thermal energy network that provides heating and cooling. The focus of the system integration is cost effectiveness, reliability and predictability of thermal energy supply. The policy and regulatory frameworks are also examined to provide the narrative necessary to permit and install such a system. Finally, engagement activities with the surrounding communities and the towns of Bryan and College Station are developed to quantify and develop community support. Numerous feasibility studies have been conducted of various campuses, but this is one of the first studies that explicitly couples the policy and regulatory framework with the technical design and development.

1. INTRODUCTION

The advent of geothermal energy in United States happened in the nineteenth century, when in 1892, the first district wide geothermal heating system was created in Boise, Idaho (Massachusetts Institute of Technology, 2009). Since then, the application of geothermal energy for heating has grown across United States, including the use of geothermal heat pumps. Across the US, the application of geothermal energy is not equally distributed, with some states having incorporated it to a far greater degree. Geothermal energy in Texas is becoming increasingly popular, with the bureaucratic and regulatory systems adapting to the growing demand.

This paper presents the economic, regulatory, and community aspects of repurposing old oil and gas wells at the Texas A&M University System's RELLIS campus, into geothermal wells for heating and cooling applications. It provides potential funding opportunities and resources with federal, state, and private entities. Similarly, regulatory streamlines are presented at federal and state levels that support the implementation and commercialization of geothermal heating and cooling for local communities. The paper also describes the stakeholders, such as the local communities, that will benefit by taking the RELLIS geothermal heating and cooling project as an example. This project could inspire many communities to crowdfund such geothermal projects for their benefit, promote its implementation in schools, hospitals, public and private establishments, and individual homes.

The project takes advantage of pre-existing oil and gas wells on the RELLIS campus limits. Repurposing them as geothermal wells, cold water is injected into one well to a zone with high permeability, where it extracts thermal energy from the rock. The heated-up water is produced from a production well. This produced water is then used to distribute heat to the campus facilities.

1.1 Repurposing Oil and Gas Wells

Repurposing old or abandoned oil and gas wells has been in consideration for quite some time. Multiple studies have been published on converting these abandoned wells for harnessing geothermal heat for heat distribution or electricity generation. Repurposing the soon-to-be abandoned wells for geothermal application could help companies to avoid or postpone the abandonment cost, which is usually a liability, and extend the economic life of the well. There are four geothermal heat harvesting methods – open loop systems where injection and production wells are directly connected to a groundwater or aquifer source; coproduction where heated water is produced along with hydrocarbons; enhanced geothermal systems (EGS) where a reservoir is artificially created in low permeability formations through stimulation, and advanced geothermal systems (AGS) where a closed loop heat exchanger is drilled in the subsurface. The first three methods can be applied to repurposing of oil and gas wells, but they come with their advantages and disadvantages. The fourth method frequently requires extensive wellbore networks and thus typically requires drilling of new wells. The primary challenges are regulatory and safety, as some of these wells may produce associated oil and gas (hydrocarbons that remain in the reservoir). The risk of leakage and subsequent mitigation of the associated hydrocarbons is a potential liability, especially to reactivate old shut-in wells. Some of the technical challenges are the geothermal gradient, dealing with cement plugs in plugged and abandoned wells, data on other formations that could be accessed for geothermal energy, and well integrity (Santos, Dahi Taleghani et al. 2022, Meenakshisundaram, Tomomewo et al. 2024).

1.2 Geothermal Energy at University Campuses

Geothermal heat pumps (GHP) are a frequently deployed systems across United States for heating and cooling uses and have been successfully deployed for campus scale projects. GHP work as ground heat exchangers, utilizing the ground's constant temperature throughout the year. Due to the temperature difference between the surface and the subsurface, the ground acts as a heat sink during the summer, and a heat source during the winter. Campuses are ideal candidates for geothermal system deployment due to existing centrally managed district energy networks. Some examples of these applications in university campuses are at Ball State University (Indiana), Colorado Mesa University (Colorado), and Miami University (Ohio). Some are centralized with a central heating plant and some are decentralized with heat pumps at each building on the campus. Ball State University's system has a heating capacity of 8,189 MBH (1,000 British thermal units per hour) and a reported net cost savings of $764,200 in 2016. Colorado Mesa University's system has a heating capacity of 32,722 MBH and at Miami University, the energy cost saving are reported to be about 64.8% of the energy cost (Oh and Beckers 2023). Overall, each of these campuses have saved significantly on the costs of electricity and gas for heat generation and consumption.

1.3 DOE Geothermal Collegiate Competition

This project was developed within the context of the Department of Energy's (DOE) 2024 Geothermal Collegiate Competition. The competition has two tracks, technical and policy. The findings of the paper represent the work of the policy team – Aggieland Visionaries. For the competition four submissions were required: site selection, economic and financial incentives, permitting and stakeholder engagement for a proposed geothermal heating and cooling system project in the United States. The competition ran from August 12th to December 20th , with an industry and academia mentor assigned to each team. The results will be announced on February 28th, 2025, with the winning team receiving $10,000 to host a stakeholder engagement event for their project.

2. SITE SELECTION

Whilst previous investigations of RELLIS's geothermal potential have been evaluated from a technical perspective, a focus on policy has until now not yet been thoroughly investigated. Technical analysis of the campus is based on Weijermars et. al.'s 2019 paper . The paper discusses the technical possibilities for EGS for dormant oil and gas wells at RELLIS campus. The wells are drilled in Austin Chalk, as depicted in Figure 1. Whilst the carbonate reservoir does not have sufficient water in place, it is naturally fractured with promising permeabilities. They estimated that the oil in place is negligible relative to the native water. The average recorded temperature of the layer is at a favorable 99°C (210°F). A total of 239 GWh has been established by their initial calculations, assuming a single pair will be producing 1000 bbl/day.

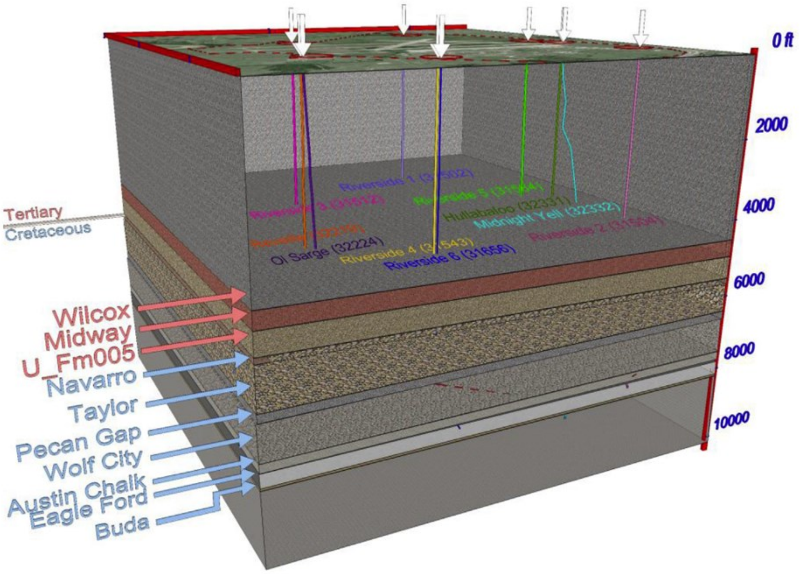


Figure 1. Well locations at RELLIS Campus (Weijermars et. al. 2019).

2.1 Brazos County

RELLIS Campus is a burgeoning hub for research, technology, and education within Brazos County in eastern Texas. The county has a rich history of oil and gas production, with over 2500 drilled wells in the 375,104 acres of land (Texas Drilling, 2024) (United States Census Bureau, 2023). As of 2024, the median household income was $58,388, with about 24% of families living below the poverty line (United States Census Bureau, 2024). Our proposal aims to support these disadvantaged communities by providing a framework for developing district heating and cooling systems using geothermal energy. By reducing reliance on traditional energy sources and lowering utility costs, residents can experience improved quality of life and financial relief. Our proposal represents a strategic alignment of environmental innovation with community development. By focusing on RELLIS Campus and extending the framework to agricultural and economically disadvantaged areas, we address multiple facets of the county's needs. This initiative positions Brazos County as a leader in renewable energy implementation, setting a model for other communities to follow.

2.2 RELLIS Campus

Formerly the Bryan Airforce base, the Texas A&M University System assumed ownership of the 1,877-acre campus in 1987 and it has been adapting to modern challenges ever since. RELLIS' development master plan states the goal of becoming "one of the nation's leading "smart" collaborative innovation and research clusters" (The Texas A&M University System, 2020). Thus, making it the ideal location to develop a large-scale geothermal heating and cooling system repurposing dormant oil and gas wells. As the campus is currently undergoing major development, this is the ideal time to implement the new technology into the system. The campus is set to expand in three phases, increasing the maximum capacity of the central utility plant from 15,000 MBH (1,000 British thermal units per hour) to 69,000 MBH (The Texas A&M University System, 2020). The campus is also conveniently located in the proximity of state highways 47 and 21, further easing the logistics of any transportation require to set up the geothermal heating and cooling system.

As aforementioned, the RELLIS Campus masterplan outlines a phased expansion that will significantly increase the heating and cooling requirements of the campus. Currently, the campus encompasses 500,000 sq. ft., necessitating 1,000 tons of cooling and 7,700 MBH of heating, supported by a Central Utility Plant (CUP) with a capacity of 2,400 tons of cooling and 15,000 MBH of heating. As the campus progresses through three phases of expansion, the demand will rise sharply, with Phase 1 adding 1,084,700 sq. ft. and requiring an additional 1,742 tons of cooling and 10,853 MBH of heating, thereby necessitating an expansion of the CUP to 3,200 tons and 18,000 MBH. Phase 2 and Phase 3 will further escalate these demands, ultimately requiring a CUP capacity of 11,500 tons and 69,000 MBH by the completion of all phases (Vespasiano et al., 2023; Benyoub, 2024; Caulk & Tomac, 2017; Zeh et al., 2021).

The economic implications of this expansion are significant. In Bryan, the cost of producing 1 MBH of heat varies by energy source, with natural gas being more cost-effective than electricity, costing approximately $0.00203 per MBH for natural gas compared to $0.03223 per MBH for electricity. This cost differential underscores the economic viability of utilizing natural gas for heating in the context of the campus expansion (Song et al., 2020; Walraven et al., 2015; Wu, 2019). Additionally, capital expenditures (CAPEX) for cooling systems in CUPs can vary widely, with air-cooled chillers costing between $450 to $1,500 per ton and water-cooled chillers ranging from $300 to $400 per ton. Operational costs are also a critical factor, with efficient systems achieving around 0.45 to 0.5 kW/ton, translating to approximately $0.075 per ton-hour at an electricity rate of $0.075 per kWh (Battaglia, 2024; Farghally et al., 2010; Ram et al., 2022).

3. ECONOMIC ANALYSIS

To assess the economic feasibility of the Geothermal District Heating and Cooling (GDHC) project of a similar equipment layout shown in Figure 1 (Gong et al., 2023), a Monte Carlo Simulation (MCS) with 100,000 iterations has been employed. This simulation divides costs into capital expenditure (CAPEX) and operating expenses (OPEX), with OPEX estimated at 10% of total CAPEX annually. The existence of dormant, naturally fractured oil and gas wells significantly cut the CAPEX cost associated with subsurface drilling & development and limited the CAPEX to mainly be the surface facilities costs shown in Table 1 (Weijermars et. al., 2019; Westphal et al., 2018). According to (Weijermars et. al., 2019), the geothermal resource under RELLIS in the Austin Chalk is estimated to be is around 239 GWh of energy and to account for the uncertainty associated with the project, the geothermal resource is projected to cover only 60% to 80% of heating and cooling needs, with a decline rate of 0.5% to 5% per year after five years of production. The savings/revenue from the project are calculated based on the estimated costs of heating and cooling consumption covered by GDHC, minus CAPEX, OPEX and depreciation as shown in equation 1 (Dinçer & Acar, 2015; Nakomčić-Smaragdakis & Dragutinovic, 2016; Mehmood et al., 2019).

$$\text{Revenue/Savings} = \text{Fraction Covered by GDHC} \times ((\text{Cooling Needs/Ton}) \times \text{Price/Ton}) + \text{Fraction Covered by GDHC} \times ((\text{Heating Needs/Ton}) \times \text{Price/Ton})) - \text{CAPEX} - \text{OPEX} - \text{Depreciation} \quad (1)$$

Table 1. Shows triangular distribution CAPEX cost breakdown.

Phase \ Cost	Most Likely Cost	Least Expected Cost	Most Expected Cost	Reference(s)
Pre-study	$10,000	$5,000	$15,000	(Zeh et al., 2021; García-Céspedes et al., 2022)
Planning and permitting	$15,000	$5,000	$20,000	(Blázquez et al., 2018; Battaglia, 2024)
Equipment selection	$8,000	$5,000	$10,000	(Farghally et al., 2010; Hałaj et al., 2021)
Equipment purchase	$500,000	$300,000	$1,000,000	(Zody & Gisladottir, 2023; , Zhili et al., 2022, Table 4 - Appendix)
Equipment installation	$30,000	$20,000	$50,000	(Moya et al., 2018; , Boesten et al., 2019)
Start Up	$30,000	$20,000	$40,000	(Dimitriu et al., 2014)

The CAPEX analysis reveals a range of costs for various project components, with the most likely costs for pre-study, planning, equipment selection, purchase, installation, and startup detailed in a triangular distribution format presented in Table 1. The cumulative net cash flow and internal rate of return (IRR) are assessed under different confidence levels, indicating a P50 IRR of approximately 25% to 26%, which is attractive for such projects. The sensitivity analysis highlights that equipment costs significantly impact total CAPEX and IRR, while NPV is most sensitive to MBH costs and the fraction of demand met by geothermal resources (Ding, 2024; Boban et al., 2021; Awaleh et al., 2021).

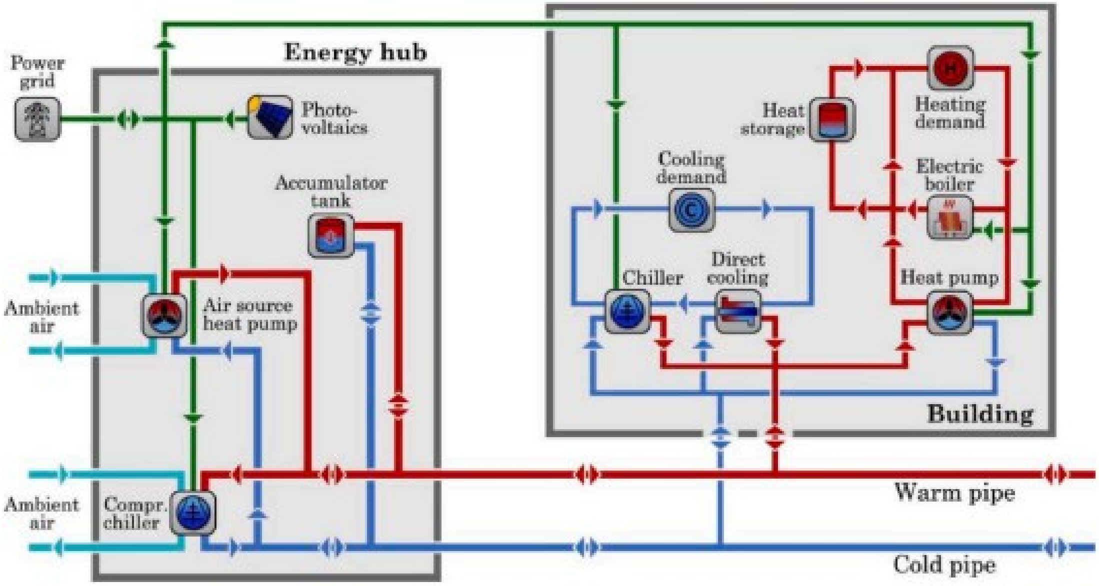


Figure 2. Structure of a similar equipment layout (Gong et al., 2023).

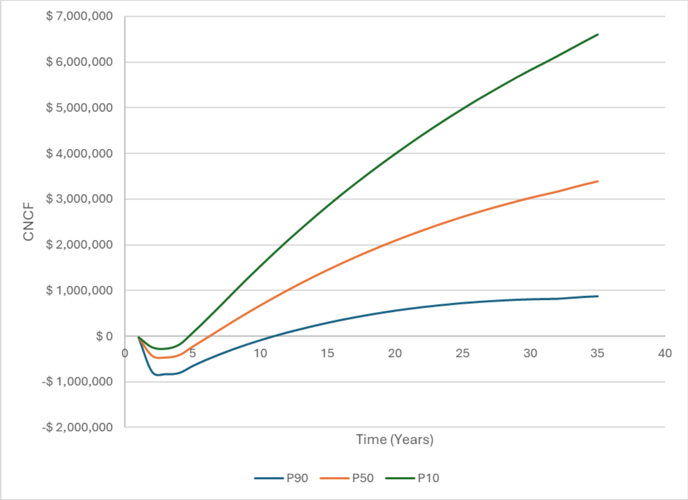
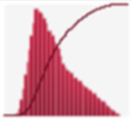
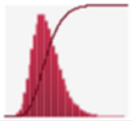
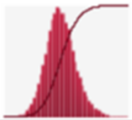
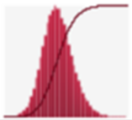
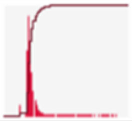


Figure 3. Cumulative net cash flow versus time for P10, P50, and P90 scenarios.

The cumulative net cash flow is shown in Figure 3 with different confidence levels, P10, P50, and P90. The project assets are considered to deprecate over 30 years and will retain zero value after this period. A 10% full cycle discount rate was adopted in internal rate of return (IRR) and net present value (NPV) calculations. The project total CAPEX has P10, P50, and P90 of approximately $260K, $445K, and $800K, respectively. The P90-P10 range for the IRR at 20, 25, 30 and 35 years are 7.9-48.3%, 9-48.4%, 9.8-48.5%, 10.6-48.6%, respectively. The wide range reflects the high uncertainties; however, IRR showed a consisted P50 of 25% to 26% which is very attractive/common of such projects. The payout time for the project has a P50 of 7 years. While the P50 of the NPV ranged between approximately $540K to $640K. Table 2 shows the detailed statistics of the parameters investigated. A sensitivity analysis has shown that equipment cost has the highest impact on total CAPEX and IRR. On the other hand, NPV is most sensitive to the cost of MBH, then fraction covered by geothermal resource and then the cost of the equipment. IRR is also sensitive to the cost of MBH, and the fraction covered by geothermal resources where they came second and third after the equipment cost.

In summary, the RELLIS Campus expansion presents a substantial increase in heating and cooling demands, necessitating careful economic analysis and planning for GDHC systems. The integration of geothermal resources offers a sustainable and cost-effective solution, aligning with broader trends in clean energy and resource efficiency (Casasso & Sethi, 2016; Yin et al., 2021; Aalhashem et al., 2022).

Table 2. Detailed statistics for Total CAPEX, IRR, NPV, and payout time.

Parameters	Total CAPEX	IRR (20 Years)	IRR (35 Years)	NPV (20 Years)	NPV (35 Years)	Payout (Years)
Distribution						
Statistic						
Mean	$ 489,310.55	27.032%	28.079%	$ 559,955.74	$ 671,348.43	7.266
Mode	$ 344,227.50	24.164%	21.257%	$ 429,493.53	$ 506,221.45	6
Std. Deviation	$ 204,689.75	16.037%	15.210%	$ 527,312.58	$ 593,151.87	3.285
Skewness	0.7315	0.5027	0.6692	0.2392	0.2822	3.6101
Kurtosis	2.8130	3.3934	3.4988	3.1281	3.1554	37.5810
Percentiles						
10%	$ 260,561.50	7.885%	10.168%	-$ 98,821.51	-$ 66,491.69	5
25%	$ 330,410	15.801%	17.094%	$ 201,286.55	$ 264,737.66	6
50%	$ 445,619.50	25.496%	26.156%	$ 537,919.53	$ 642,313.34	7
75%	$ 616,538.50	36.863%	37.246%	$ 896,060.45	$ 1,046,418.66	8
90%	$ 800,417.50	48.324%	48.600%	$ 1,248,828.50	$ 1,447,678.04	10

4. PERMITTING

EGS is a technology that is quickly evolving, with the permitting framework lagging behind the technical advancements. This paper provides a preliminary overview of what the permitting framework for an EGS project that repurposes dormant oil and gas wells would look like at a federal, state, and local level. Whilst the current available information is ambiguous at times due to the new technology, the information provided is to the best of our abilities. This section reflects the policy stance as of January 1, 2025 and does not reflect any changes in policy and funding enacted in 2025.

4.1 Federal

As the RELLIS campus project is not situated on any federal lands, and Texas A&M University systems owns both the mineral and surface rights, this greatly simplifies the process (Weijermars, et al., 2018). Depending on the funding sources that the project will have, the National Environment Policy Act (NEPA) will be applicable if there is federal funding. Signed into law in 1970, NEPA requires a thorough analysis of the environmental and socio-economic implications of the project (United States Environmental Protection Agency, 2024).

4.2 State

Most geothermal wells permits have transferred from the Texas Commission of Environmental Energy (TCEQ) to the Texas Railroad Commission (TRRC) as of September 31st, 2023. The TRRC has adopted all the previous rules, standards and forms of the TCEQ, and currently does not plan on altering them at the present time (Texas Railroad Commission). The TRRC identifies 9 different sections for a geothermal permit, the different sections and the permits that accompany them are listed below. As this project involves changing the classification of the dormant oil and gas wells, additional permits are needed compared to a classical EGS. Currently permits for all geothermal wells fall under the same category. This is where groups like TEXGEA are currently looking to improve the current legislation to not only streamline permitting, but also adapt it to best fit the technology

4.2.1 Converting oil and gas production wells

When it comes to converting an abandoned oil and gas well to a water production well, both Texas Natural Resources Code (Section 89.011) and TRRC (Section 3.14(a)(4)) allow a landowner and operator to do so. Whilst uncommon, the process is not novel with over 1,500 oil and gas wells having been converted as of 2001 (Texas Railroad Commission 2024). Form P-13, “Application of Landowner to Condition an Abandoned Well for Fresh Water Production” must be filed for the application. Here current and future liabilities of the well are passed to the landowner related to the past oil and gas operations. There is a current lack of clarity on what the process would be if the oil and gas well is converted to a water injection well (class V).

3.2.2 Geothermal Leasing

No geothermal leasing is necessary as both the land and the mineral rights are owned by Texas A&M University systems (Weijermars, et al., 2018). Forms P-5 and P-4 are required for information on the organization report and the leaseholder of the well respectively. If any changes to the well, whether for drilling, reentering, or deepening the well, form W-1 is necessary. Furthermore, completion information must be disclosed in forms W-2/G-1. It is necessary to submit the form within 30 days of completion. This is the one of the two sections where hydraulic fracturing can be reported in the current state’s framework, differentiating it from a classic geothermal system. It is currently the only form differentiating a conventional geothermal project compared to an EGS that requires hydraulic fracturing. Then form GT-1 is necessary to report the production, (re)completion report and log, as well as GT-2 for the producer’s monthly report of the wells.

For injection in geothermal projects, Texas requires extensive permits to be filled out. For the injection well permit, forms GT-5 and H-1A, H-7 and freshwater injection questionnaire are necessary. Then the injection well construction requires details on the casing and injectate to assure that they are compatible. The well diagram and as well as justification if tubing and packer, or surface casing are not integrated in the design. A description of the planned completion of the injection well is necessary, this would be the place to note the hydraulic fracturing. To ensure the safety of operating the injection well, additional information is required. The Maximum Surface Injection Pressure or a method to establish said value. Furthermore, a description of the injection purpose and procedures is necessary. As the whole life cycle of the project must be considered, information on the lifetime of the facility must be provided as well as the conditions in which the facility will close and the method for the closure.

Conducting a mechanical integrity test (MIT) is essential for the safety of the project. This is why it must be performed prior to the injection and annually, all the results must be filed online in the H-5 form. A description of the gauges, accompanied with the procedures for well head pressure monitoring must be included in the submission. Furthermore, the frequency, methods, and procedures for testing the injectate water quality must be reported, as well as the scheduled frequency of the reports to the Commission must be provided. Data on logging and well testing must be reported within 30 days. Regarding injection reporting, the form H-10 regarding annual disposal/injection well monitoring report is necessary.

4.3 Local

At the Brazos County level, there is currently no concrete framework in terms of enhanced geothermal systems. Whether these wells will be treated as oil and gas wells, or water wells is still up for debate. As part of the stakeholder engagement, the Brazos County local government will play an essential role. In doing so, new policies will have to be established so that this project may take place.

5. FUNDING

To successfully implement a geothermal direct heating and cooling system at the RELLIS campus, various federal, state, and private financing sources can be pursued to minimize the cost to the university and maximize the financial stability of the project. As funding is dependent on the classification of the institution, Texas A&M is classified as a public land grant university.

5.1 Federal

It is important to keep track of the different federal opportunities that are provided by the Department of Energy's Geothermal Technologies Office (GTO). The GTO focuses on advancing geothermal technology and often awards competitive grants that could contribute up to millions of dollars toward upfront costs. Whilst the Inflation Reduction Act is only valid for projects that started building prior to 1/1/25, it is an example of federal incentives and can be indicative of what future federal incentives may look like (The White House, 2023). The act provided a constant source of savings as the project ages through the form of tax credits, with bonuses available based on the content of domestic content and meeting certain labor requirements.

5.2 State

Diversifying the funding and financing profile ensures a more financially responsible project and increases the likelihood of acquiring the necessary monetary resources. Texas offers several financial programs tailored to energy projects, such as the LoanSTAR Revolving Loan Program (10 Tex. Gov. Code §2305.032), funded by the Texas State Energy Conservation Office (SECO), provides another option for low-interest loans for energy efficiency upgrades in public institutions. Being a public university campus, RELLIS would be entitled to the repayment and reinvestment though realized energy savings offered by the LoanSTAR program. The Texas Commission on Environmental Quality (TCEQ) through the New Technology Implementation Grants offers grant incentives for energy-efficient projects for up to 50% of the costs (Texas Commission on Environmental Quality). Whatever cost is not covered, the low- risk loan programs offered by the state of Texas can be acquired for the missing funding.

5.3 Private

Finally, private funding from an entity such as the U.S. Energy Foundation could provide some funding. It has previously worked with Texas A&M, granting up to $97k in grants (U.S. Energy Foundation). There is also the possibility of donors supporting the project. The goal is to cover as much of the cost as possible from other sources before turning to the generosity of the Alumni.

6. WORKFORCE ASSEMENT

Geothermal district energy systems play a significant role in local employment creation, providing numerous job opportunities during both the construction and operational phases. This workforce assessment analysis offers a detailed look at the job creation, training requirements, upskilling opportunities, and economic incentives associated with geothermal heat pump (GHP)-based district energy systems, based on insights from five existing projects: Ball State University, Colorado Mesa University, Miami University, West Union, and University of Connecticut.

6.1 Workforce Assessment Analysis

Geothermal district energy systems across these five institutions significantly impacted local workforce development. The construction phase is especially labor-intensive, involving activities such as borehole drilling, pipe installation, and integration of geothermal systems. Additionally, the operational phase requires a workforce capable of managing, maintaining, and optimizing these systems. The five geothermal projects assessed provide valuable insights into workforce needs, indicating that both skilled and semi-skilled workers are essential for the successful deployment of GHP systems.

6.2 Job Creation and Employment Statistics

Geothermal district systems create significant employment through direct, indirect, and induced opportunities compared to other renewable energies. The number of jobs created is dependent on the scale of the project, the values for Ball State University and West Union are presented to depict this range. Ball State University has a heating capacity of 2.4 MW, with a cooling capacity of 10,000 tons; this created roughly 2,300 job opportunities (Oh & Beckers, 2023) (Ball State University). For a much smaller project of 264 tons of heating and cooling capacity for the geothermal heating and cooling project in West Union, Iowa, 85 jobs were created (Green Up West Union) (U.S. Department of Energy, 2013). As RELLIS campus is within the magnitude of Ball State University's project, we can expect similar values for the number of jobs created.

6.3 Training Requirements

The transition to GHP systems necessitates specialized training for both new employees and upskilling for existing workers. Construction roles require training in borehole drilling, pipe installation, and geothermal system integration. Meanwhile, the operational phase demands training for monitoring system performance, managing heating and cooling loads, and optimizing efficiency. For the University of Connecticut project, workshops were held to identify gaps in the current local workforce's knowledge and initiatives to seal said gaps (Northeast Energy Efficiency Partnerships, 2024). It is important for projects to establish said workshops in advance to ensure that the workforce can remain local, and thus better benefit the local community.

6.4 Upskilling Opportunities and Incentives

There is a growing need for technicians and engineers to stay updated with the latest innovations in system optimization and monitoring. For instance, learning to operate advanced geothermal system software, training in sustainable energy practices, and understanding new performance metrics are all areas for skill enhancement. Government incentives, such as federal and state tax credits, have been instrumental in promoting workforce development in the geothermal sector. These incentives encourage companies and institutions to invest in employee training programs, enhancing the skills of geothermal system operators and technicians, thus ensuring the long-term success and sustainability of geothermal projects.

7. STAKEHOLDER ENGAGEMENT

Proper stakeholder engagement is essential for the success of integrating a new technology in a society. Depending on where a geothermal project is located, there will be varying degrees of knowledge on the topic and different points of concern (Pellizzone, Allansdottir, De Franco, Muttoni, & Manzella, 2017). To adequately address the concerns of the stakeholders, Figure 4 was produced for the project on RELLIS.

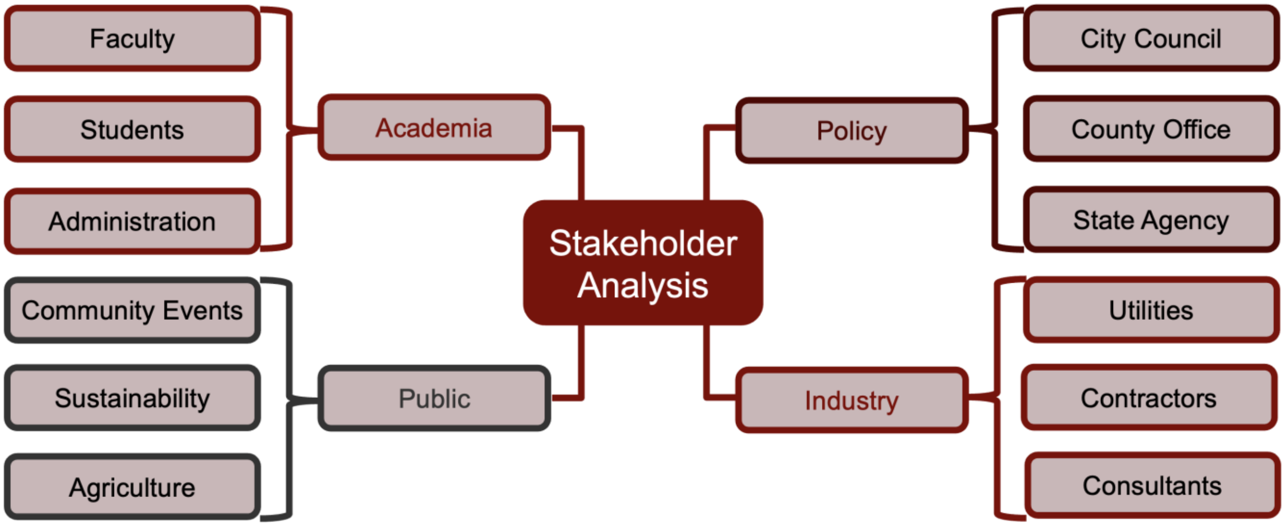


Figure 4: Stakeholder engagement map for RELLIS.

There are four major groups to target in the project: academia, the public, politics, and industry. As part of the DOE Geothermal Collegiate Competition, the initial phase of stake holder engagement was started. During this process, all four groups were targeted, with an initial focus on the academia section.

7.1 Academia

To align the project's priorities with faculty at RELLIS campus, video calls and emails were used to communicate with the System Land Management Office as well as leadership at RELLIS campus. Key takeaways from these meetings were information on their current system and the best strategy to incorporate a compatible geothermal heating and cooling system.

An informational session was hosted for the Honors Student Council to engage the student body. This proved to be an essential event as many students of the 60 students attending had not heard about this technology before. After the event they felt positively towards it and were keen on its integration on campus.

The Office of Sustainability and Campus Enrichment was contacted on promoting geothermal energy on campus, they directed the team to Aggies Recycle Day hosted by Utilities and Energy Services. This event was another opportunity to inform, promote and establish the current level of understanding of geothermal energy at Texas A&M. The event found that 14% of the people asked either used or knew someone that used geothermal energy. This low number stresses how geothermal energy is severely underutilized in the region thus far.

7.2 General Public

Whilst the different entities listed in Figure 4 were contacted, no response was received. This could be due to the lack of interest given the context of the collegiate competition. If this project is to go forwards, events such as local city council meetings would be a starting point in further reaching the non-university affiliated public. It would also be advisable to apply well in advance to assure success in being accepted.

7.3 Industry

Industry was contacted to discuss what their current challenges were and how this project could avoid them. Calls with Geothermal Rising, Exceed Geo Energy and Texas Geothermal Energy Alliance all provided useful insight and other projects in the region that can be used as examples. Furthermore, the Texas Geothermal Energy Alliance contact had expressed appreciation of the clear representation of the geothermal permitting process.

7.4 Politics

A Texas Railroad Commission member was contacted on the current stance of permitting for geothermal heating and cooling prospects was. It was noted that a structured layout of the permits had not yet to be compiled in Texas and expressed enthusiasm due to the clear representation of the steps that had to be taken for future parties.

7.5 Next Steps

It was also evident that a clear roadmap of geothermal permitting necessary was appreciated and would bring value to future entities looking to implement geothermal heating and cooling systems. Furthermore, from conversations with the students, it is evident that there is a lack of knowledge on geothermal energy and its use cases in Brazos County. If the RELLIS project is to take place, further education must be provided to the community. This is why a stakeholder engagement in collaboration with Texas A&M Geothermal Research Opportunities Symposium was proposed if the DOE is to select this project as the winning project for the Geothermal Collegiate Competition. The goal of the event will be to demonstrate the implementation and benefits of geothermal heating and cooling systems, with a focus on sustainability and reduced energy consumption. RELLIS Campus will be showcased as a model to encourage adoption by other sectors. So far only students were being educated on the geothermal energy, however this event would facilitate reaching a larger target that includes residents, business owners, educators, industry partners, local government representatives and faculty at Texas A&M.

8. CONCLUSION

This paper provides the economic, regulatory and policy viability of an on campus integrated geothermal enhanced geothermal system repurposing dormant oil and gas wells. The Monte Carlo simulation for the technoeconomic analysis showed that a geothermal heating and cooling system can economically supply RELLIS campus with 60% to 80% of its demand. This case study documented the current permitting framework, highlighting unclarities and areas of improvement. This is expected to change in the next few legislative periods, as TRRC has stated its intentions of working with industry and academia to adapt the permits to the evolving technology. The funding analysis ascertained that geothermal energy is well supported at the private, state and federal level. If the funds cannot be completely covered by grants, there are attractive loan options that this project is eligible for. The workforce assessment, evaluating other geothermal heating and cooling projects, yielded valuable strategies to ensure a local workforce and positively contribute to the local economy. Finally, the stakeholder analysis identified the potential stakeholders of the project. The initial stage of the stakeholder engagement stressed the lack of information on geothermal energy in Texas, which could be the main cause of deficiency of preliminary enthusiastic responses from the public. Moving forwards, it is vital for the success of geothermal energy to spread awareness of what it is and how it can benefit local communities. No prior literature has focused on the non-technical aspects of an EGS in Texas, let alone one that simultaneously repurposes the dormant wells. It is important to not only continue the technical advancements on these technologies, but to also start addressing the economic, regulatory and policy implications to prevent the gap between the two from widening,

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APPENDIX

Table 3. Estimated cost of the equipment.

Equipment	Estimated price
Ground Source Heat Pumps (GSHP)	
Horizontal Loop Systems	$3,100 to $4,700
	$4,000 to $6,500
Heat Exchangers	
Primary Heat Exchanger	$20,000 to $100,000
Secondary Heat Exchanger (Optional)	$10,000 to $80,000
Pump	
Geothermal Fluid Pumps	$300 to $2,500
Circulation Pumps	$500 to $1,000
Distribution Network	
Insulated Pipelines (HDPE)	$2 to $4 per foot
Expansion Joints (price/joint)	$100 to $500
Control Valves	$300 or $1,500
Manifolds	$200 to 1000$
Heating/Cooling Equipment in Buildings	
Radiators	$100 minimum
Fan Coils	$1,000 to $ 2000
Underfloor Heating Systems	$2,000 to $4,000
Air Handling Units	$3,000 to $15000
Chilled Beams	$5.70 per foot
Control Systems	
Building Management Systems (BMS)	$5,000, to $50000
Smart Thermostats	$20,000 to $100,000
Flow Meters	$1,000 to over $10,000
Temperature Sensors	$50 to $500 each
Pressure Sensors	$50 to $500 each
Thermal Energy Storage (Optional)	
Hot Water Storage Tanks	$300 to $1500
Cold Storage Tanks	$10.129,99
Backup Systems	
Auxiliary Boilers	$25,000 to $500,000,

Cooling Towers/Chillers	$15,000 to $100,000
Electrical Components	
Transformers and Switchgear	$1500 to $5000
Inverters/Converters	$1,000 to $10,000
Uninterruptible Power Supply (UPS)	$200 to $25,000
Maintenance and Monitoring Equipment	
Corrosion Control Systems	$100 to $150