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DEI Double Energy Input, 5.1, optimisation of the previous model

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ABSTRACT

To mitigate the escalating adverse effects of anthropogenic activities—such as global climate change and ecosystem degradation—there is an urgent need to develop alternative energy sources that are clean, renewable, and efficient. These energy sources must be capable of replacing or significantly reducing our dependence on traditional fossil fuels, which are major contributors to greenhouse gas emissions.

The Double Energy Input (DEI) system represents a novel technological advancement that integrates two renewable energy resources: hydroelectric power and geothermal energy. This innovative system leverages the thermal properties of geothermal heat to warm pressurized water, utilizing the sea as a natural coolant to enhance efficiency. In this design, a separate chamber operates a steam-powered turbine, effectively converting geothermal heat into mechanical and electrical energy. By harnessing two abundant natural forces—heat and pressure—this model offers a sustainable and efficient alternative for the production of clean energy. The synergy between these renewable resources provides a promising approach for addressing global energy demands while mitigating environmental impacts.

1. INTRODUCTION

1.1 Greenhouse Gases and Their Impact on the Planet The influence of greenhouse gases on Earth's climate is both fundamental and complex. According to the Joint Science Academies (2005), greenhouse gases play a critical role in maintaining life-supporting temperatures on Earth. Without them, global average temperatures would be approximately 30°C lower, rendering much of the planet uninhabitable. However, human activities have significantly altered the natural balance of greenhouse gases in the atmosphere.

Since the onset of the industrial revolution, the atmospheric concentration of carbon dioxide (CO_2)—one of the primary greenhouse gases—has risen alarmingly, from pre-industrial levels of approximately 280 ppm in 1750 to over 375 ppm today. This rise has been accompanied by a measurable increase in global temperatures, with the Earth's average temperature increasing by approximately 0.6°C during the 20th century. Projections by the Intergovernmental Panel on Climate Change (IPCC) indicate that, if current trends continue, global surface temperatures could rise between 1.4°C and 5.8°C above 1990 levels by the end of the 21st century. Such a scenario would have profound consequences for ecosystems, weather patterns, and human societies worldwide.

1.2 The Escalating Demand for Energy Throughout history, humanity's energy needs have grown in tandem with technological and societal progress. The advent of industrialization marked a pivotal moment, with fossil fuels such as coal, oil, and natural gas rapidly supplanting traditional energy sources like wood and biomass. This transition fueled unprecedented economic growth but also laid the foundation for the environmental crises we face today.

The trajectory of energy demand continues to accelerate. The aerospace and information technology revolutions, coupled with rising living standards across the globe, have placed immense pressure on existing energy infrastructures. Meeting these demands requires innovative solutions capable of producing energy sustainably and at scale.

1.3 The Role of Renewable Energy in Mitigating Climate Change In recent decades, renewable energy technologies have emerged as critical tools in the fight against climate change. Solar and wind energy, in particular, have seen remarkable advancements, with both sectors experiencing significant growth in capacity and efficiency. However, reliance on a single renewable source may not always be sufficient to address the diverse and fluctuating energy needs of modern societies.

The development of hybrid systems, such as the Double Energy Input (DEI) model, presents a compelling pathway forward. By integrating complementary renewable resources, such systems can enhance reliability, optimize resource utilization, and reduce environmental impacts. Renewable energy is no longer an optional solution; it is an essential component of the global strategy to combat global warming, reduce pollution, and preserve ecosystems for future generations.

2. DEI PREVIOUS MODELS AND CHALLENGES

2.1 DEI Previous Models The development of the Double Energy Input (DEI) system has undergone multiple iterations, with three primary models—DEI I, II, and III—proposed as hybrid energy solutions that integrate hydroelectric and geothermal power generation. These models utilize the sea as a natural reservoir and tap into geothermal heat sources located at the bottom of a vast open pit to produce thermal energy. The fundamental concept relies on the gravitational potential energy created by the vertical difference between sea level and the pit's bottom, coupled with the kinetic energy of water flowing through the system.

In the DEI II model, for instance, the open-pit design was central to its operation, where seawater would be channeled into the pit and subjected to geothermal heat at depth. This process generated steam to power turbines while simultaneously harnessing hydroelectric energy as water descended to the geothermal heat source. The integration of gravity, heat, and pressure in this system exemplified a novel approach to renewable energy generation.

The models also emphasized energy storage potential. By utilizing the sea as a vast, inexhaustible reservoir and a heat exchange system, the DEI design ensured a consistent energy supply, unaffected by diurnal or seasonal fluctuations, which are common limitations in solar and wind energy systems. The concept held significant promise as a dual-input system for achieving high energy output with renewable resources. (See Figure 1)

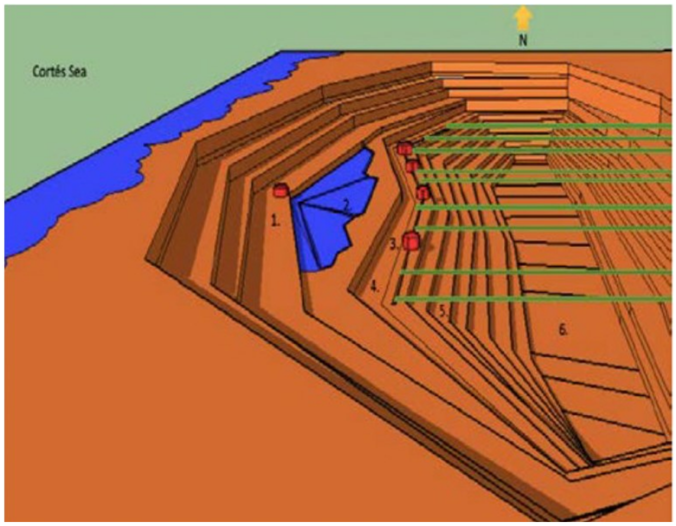

Figure 1: DEI II, Open pit model, was proposed to produce energy using the sea, gravity and geothermal energy.

2.2 Challenges with the Previous DEI Models While the DEI models presented an innovative pathway for energy generation, they faced several technical, economic, and environmental challenges that complicated their implementation:

1. High-Pressure Environment in Deep Drilling: Extreme pressures encountered at greater depths posed structural integrity and safety risks, including blowouts and collapses. Advanced control systems increased operational costs and complexity.

2. Economic and Environmental Impact of Excavation: Open-cast mining techniques required for large-scale excavation caused habitat destruction, water contamination, and other significant environmental consequences (Ghanizadeh Zarghami et al., 2019).

3. Groundwater Management and Leakage Risks: Groundwater infiltration threatened the efficiency of geothermal processes and required costly water management systems.

4. Regional Suitability and Scalability: Geographic factors, such as Mexico's Sonora Desert vs. regions with high water tables, limited the system's scalability.

5. Long Construction Times and High Investment Costs: Prohibitively long timelines and high upfront costs deterred widespread adoption. (See figure 2.)

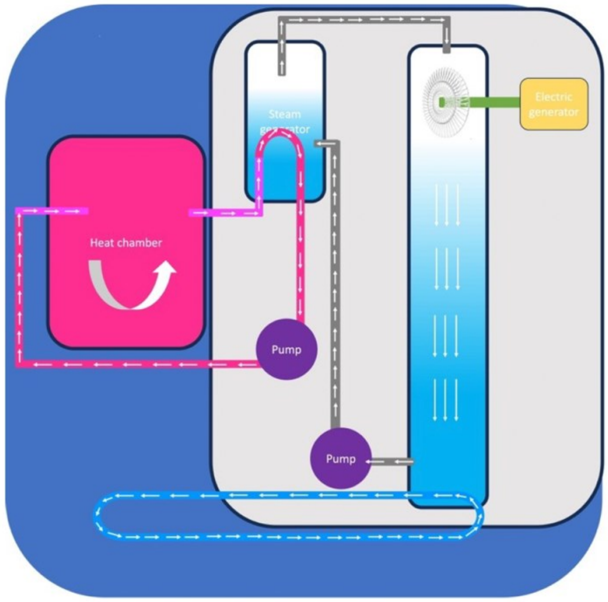

Figure 2. DEI V Electricity production diagram, undersea model.

2.3 Conclusions of the Previous Studies The earlier DEI models validated the theoretical feasibility of combining hydroelectric and geothermal energy sources. However, transitioning to practical applications revealed significant barriers, including high costs, environmental risks, and geographic limitations. Future iterations must address these challenges with advanced materials, improved designs, and innovative engineering solutions.

3. DEI 5.1: INNOVATION IN A SIMPLIFIED NEW MODEL

3.1 Introduction

3.1.1 Background Geothermal energy is an established renewable resource harnessed from the Earth's internal heat. This energy is sustainable, environmentally friendly, and capable of producing electricity continuously. However, scaling geothermal systems to compete with nuclear plants in terms of capacity remains a technical challenge. This paper investigates a novel geothermal system designed to achieve continuous 2 GW electricity production while maintaining economic viability.

3.1.2 Motivation The motivation behind this study is to explore scalable geothermal solutions that meet global energy demands, reduce dependency on fossil fuels, and minimize environmental impact. The system design combines geothermal heating with optimized thermodynamic cycles to deliver continuous power generation at industrial scales.

4. SYSTEM DESIGN

4.1 Overview of the Proposed System

The proposed geothermal system features a closed-loop configuration with the following key components:

Figure 3: Landscape overview of the Thermal power plant.

Primary Reservoir: A 100,000 m³ water reservoir located at 1,000 meters above sea level (this is represented with the mountains at the background).

Pipeline Network: A vertical pipe descending to 4,000 meters below sea level, transitioning to a horizontal segment spanning multiple kilometres (look at the Figure 4).

Heat Absorption Zone: A high-temperature geothermal region with a gradient of 90°C per kilometre.

Output Reservoir: A 10,000 m³ water reservoir at sea level, facilitating the return flow and energy transfer to a turbine-based thermal plant.

4.2. Energy Potential Calculations

4.2.1 Potential Energy of the System

The gravitational potential energy of the system is a critical component in assessing the initial energy available due to the elevation of the primary reservoir. The reservoir is located at an elevation of 1,000 meters above sea level, and its potential energy is calculated using the formula:

$$E_p = \rho \cdot V \cdot g \cdot h$$

Where:

- ρ is the density of water, assumed to be 1,000 kg/m³ for standard conditions.
- V is the volume of water stored in the reservoir, which is 100,000 m³.
- g represents the acceleration due to gravity, taken as 9.81 m/s².
- h is the elevation above the reference point (sea level), which is 1,000 meters.

Substituting the values into the formula gives:

$$E_p = 1,000 \cdot 100,000 \cdot 9.81 \cdot 1,000$$

This results in a gravitational potential energy of **981 GJ**. This energy represents the potential for mechanical work or energy conversion as water flows down through the system, driving turbines and contributing to the generation of electricity.

4.3 Thermal Energy Extraction

The system leverages geothermal energy by operating at significant depths below sea level, specifically reaching up to 4 kilometres into the Earth's crust. At these depths, the geothermal gradient—measured as the rate of temperature increase with depth—is approximately 90°C per kilometre. Consequently, at 4 km depth, the temperature of the geothermal resource reaches approximately 360°C.

To maximize energy extraction, the system employs supercritical water as the working fluid. Supercritical water exists at high temperature and pressure, allowing it to achieve exceptional thermodynamic properties. These properties include:

1. Increased thermal conductivity: Enhances heat transfer rates from the geothermal source.
2. High specific heat capacity: Allows greater energy absorption per unit mass of water.

The thermal energy extracted at this stage drives the thermodynamic cycle, converting heat into mechanical and electrical energy with high efficiency.

4.4 Power Generation and Efficiency

4.4.1 Thermal Cycle Efficiency

The conversion of thermal energy to electricity is governed by a thermodynamic cycle, typically based on principles such as the Rankine or Brayton cycle. In this system, a cycle efficiency of 59.6% is achieved. This efficiency is significantly higher than conventional geothermal systems due to the use of supercritical water and advanced heat exchange mechanisms.

The electricity output is calculated using the formula:

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$$Pe = \eta \cdot Q$$

Where:

η is the cycle efficiency (59.6%)

Q is the thermal energy input derived for the geothermal source.

Given the thermal energy input, the system is capable of producing a continuous electrical output of 2 GW, ensuring a high capacity suitable for large-scale power distribution.

4.5 Optimization for 2 GW Capacity

4.5.1 Increasing Heat Absorption

To meet the target capacity of 2 GW, additional optimizations are implemented. The length of the horizontal pipeline, which traverses the geothermal zone, is extended to 10 kilometres.

This extension provides:

1. **Increased contact area**: Enhances the surface area available for heat exchange with the surrounding geothermal rock.
2. **Higher thermal transfer rates**: Maximizes the energy absorbed by the working fluid.

These modifications ensure that the thermal energy extracted from the geothermal source is sufficient to sustain the required power output.

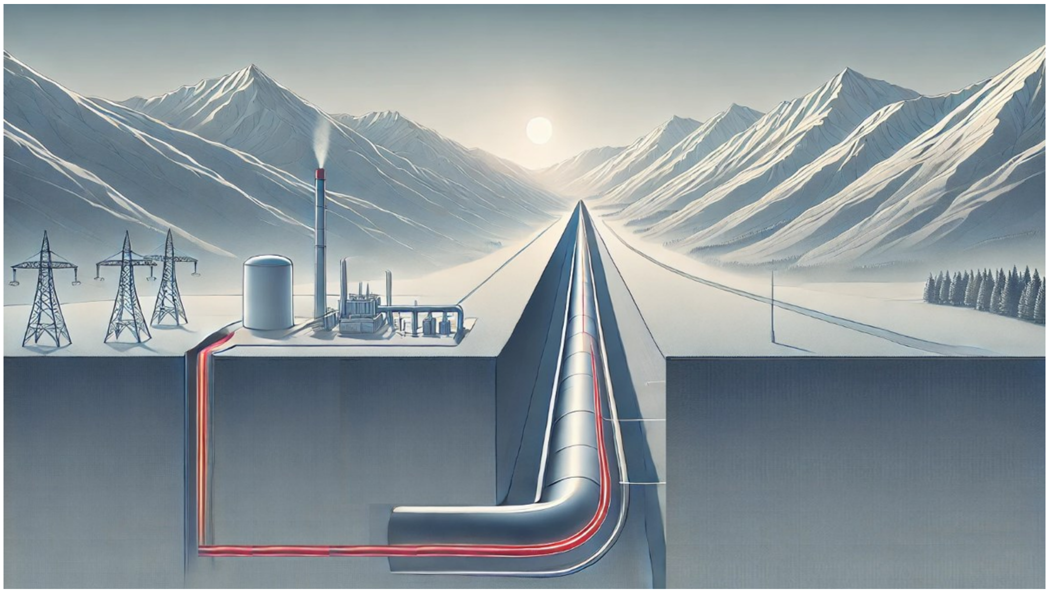

Figure 4: Schematic of the Geothermal System, the geothermal exchange will be done at 4 kilometres below the sea level, and in an extended longitude of 10 kilometres.

4.5.2 Design Improvements

Several engineering advancements are incorporated into the system design to enhance performance and reliability:

1. High-strength, thermally resistant materials: Pipelines are constructed using advanced alloys such as reinforced steel. These materials withstand extreme temperatures and pressures, ensuring durability.

2. Advanced insulation: Specialized insulation coatings are applied to minimize heat loss during fluid transport. This improves overall system efficiency by preserving the energy carried by the working fluid.

The accompanying schematic diagram illustrates the complete configuration of the geothermal system. Key components include:

- Vertical pipelines extending to depths of 4 km.
- Horizontal pipelines spanning 10 km through the geothermal zone.
- The power plant infrastructure for converting thermal energy to electricity.

5. ECONOMIC ANALYSIS

5.1 Cost Estimate and comparison with Nuclear Power Plants.

The estimated cost of constructing the geothermal plant is $10.37 billion, broken down as follows:

Drilling and Pipeline Installation: $5 billion

Power Plant Infrastructure: $3 billion

Operational Costs (30 years): $2.37 billion

A nuclear plant with equivalent capacity typically costs $18.42 billion. Thus, the geothermal system is more cost-effective by approximately 44%.

6. ENVIRONMENTAL SUSTAINABILITY IN A DOUBLE ENERGY INPUT SYSTEM

The Double Energy Input system enhances environmental sustainability by combining the inherent benefits of geothermal energy with the efficiency of an innovative dual-source mechanism. This system addresses key sustainability concerns while significantly improving energy output and minimizing environmental impact.

6.1 Benefits of the Double Energy Input System

6.1.1 Ultra-Low Emissions The Double Energy Input system achieves exceptionally low emissions through its reliance on clean energy sources: geothermal and hydroelectric energy. Unlike fossil fuels, which release significant quantities of CO_2, methane, and other pollutants, the primary emissions in this system arise from minimal maintenance-related activities. Even during high-capacity operations, the system avoids the need for combustion processes, ensuring negligible greenhouse gas emissions and aligning with global decarbonization goals.

6.1.2 Enhanced Sustainability Through Resource Reinjection A key feature of the system is its closed-loop water reinjection design. By reintroducing water back into the geothermal reservoir after heat extraction, the system:

Maintains reservoir pressure, ensuring the geothermal heat source remains viable over extended periods without depletion.

Prevents land subsidence, a common issue when geothermal fluids are extracted without reinjection.

Facilitates long-term thermal stability, as reinjected water is naturally reheated over time by the Earth's heat, creating a renewable cycle of energy production.

6.1.3 Maximized Efficiency with Dual Inputs By incorporating a secondary energy source (e.g., solar thermal), the Double Energy Input system reduces reliance on single-source energy extraction, allowing for higher overall energy efficiency. This dual input also means less geothermal fluid is required per energy unit, preserving the geothermal reservoir for longer periods and reducing strain on natural resources.

6.1.4 Minimal Land Use and Ecosystem Disruption Geothermal plants are compact compared to other renewable energy sources, such as solar or wind farms. The addition of tunnelling preheating requires only underground supplementary infrastructure, leaving the surrounding ecosystem largely intact. The underground nature of much of the geothermal system further minimizes visual and ecological impact, making it an environmentally discreet energy solution.

6.2 Challenges in Adopting a Double Energy Input System

6.2.1 High Initial Investment Costs The enhanced complexity of the Double Energy Input system necessitates higher upfront capital compared to conventional geothermal systems. Key contributors to these costs include:

Advanced drilling technologies required for deeper wells to access geothermal heat at depths of 4–5 kilometres, the technology used is the directional drilling.

Durable materials for pipelines and turbines that can withstand supercritical temperatures and pressures while maintaining system longevity.

Underground thermal exchange the pipelines require thermal materials to exchange the heat of the underground rock.

Isolation of the external deposit the preferred material should allow solar heat to add heat to the system but give isolation to the rest of the deposit of the cooling effect of the wind and water.

While these costs are significant, they are offset over time by the system's higher energy output, increased efficiency, and reduced operational expenses due to its reliance on renewable resources.

6.2.2 Site-Specific Feasibility The system's success depends heavily on the geological and solar potential of the chosen site. For geothermal energy, high heat flow regions with sufficient permeability and fluid availability are essential. Simultaneously, effective solar preheating requires locations with abundant solar irradiance. Conducting detailed feasibility studies to identify sites that optimize both geothermal potential is a critical step in project planning.

6.2.3 Operational Complexity The integration of two energy inputs—geothermal and solar thermal—requires advanced engineering and operational expertise. This includes:

Synchronizing heat input from both sources to maximize efficiency without exceeding material tolerances.

Managing the capacity of the reservoir integrity while preventing thermal depletion.

6.2.4 Environmental Monitoring Although the system minimizes emissions and ecological disruption, continuous monitoring is essential to address potential challenges such as:

Seismic risks associated with deep drilling and reinjection.

Heat plume management, ensuring surrounding environments are not adversely affected by thermal changes.

CONCLUSION

The Double Energy Input system represents a significant advancement in the field of renewable energy technologies, integrating geothermal and hydroelectric energy sources to achieve sustainable and highly efficient power generation. This innovative approach leverages the complementary characteristics of these two renewable resources to address both reliability and efficiency challenges, thereby contributing to the global transition toward a cleaner and more sustainable energy infrastructure.

Geothermal energy forms the core of the system, utilizing heat from the Earth's interior to provide a consistent and dependable base-load power supply. This energy source is inherently stable and unaffected by diurnal or meteorological variations, making it a reliable foundation for continuous energy generation. The integration of these two energy sources results in a synergistic effect that increases overall efficiency, mitigates intermittency issues, and reduces reliance on non-renewable energy resources.

Despite its numerous advantages, the implementation of the Double Energy Input system faces certain technical and economic challenges. The initial capital investment for constructing and integrating the geothermal components is considerable. This includes costs associated with drilling for geothermal reservoirs, and building the infrastructure required to combine these technologies effectively. Furthermore, the feasibility of the system is highly site-dependent, as it requires access to geothermal resources with sufficient thermal gradients and locations with high solar irradiance. These limitations necessitate comprehensive site assessments, careful resource mapping, and the development of advanced engineering solutions to optimize the deployment of the system across various geographies.

From an environmental perspective, the Double Energy Input system offers significant advantages over conventional fossil fuel-based energy production methods. The system generates minimal greenhouse gas emissions, thus contributing to the reduction of anthropogenic climate change. Additionally, both geothermal and hydroelectric energy rely on renewable resources—heat from the Earth's core and solar radiation—that are effectively inexhaustible on human timescales. The system also requires less land area compared to other renewable technologies, such as wind or solar photovoltaic farms, thereby minimizing habitat disruption and land-use impacts.

The integration of these dual energy sources establishes a new benchmark for innovation in renewable energy systems. The combined use of geothermal and hydroelectric energy enhances the system's efficiency and operational flexibility while simultaneously improving grid reliability and energy security. These characteristics make the system suitable for a wide range of applications, from large-scale industrial power generation to localized, distributed energy solutions for remote or off-grid communities.

Beyond its technical and environmental benefits, the Double Energy Input system has broader implications for economic and social development. Its deployment could stimulate job creation in renewable energy sectors, promote advancements in associated technologies, and facilitate sustainable economic growth, particularly in regions with abundant geothermal and solar resources. Furthermore, the system's scalability allows for adaptation to varying energy demands, ranging from small-scale projects for local communities to utility-scale operations.

In conclusion, the Double Energy Input system represents a transformative step forward in renewable energy research and application. By harnessing the complementary strengths of geothermal and hydroelectric energy, it provides a sustainable and efficient pathway for addressing global energy demands while minimizing environmental impact. Although challenges related to cost and site-specific feasibility remain, ongoing technological innovation and strategic planning can enable the widespread adoption of this technology. As such, the Double Energy Input system is poised to play a pivotal role in advancing renewable energy solutions and contributing to a more sustainable energy future.

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