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# **Thermal Stage**

***Thermal Stage* undermines the stereotype of geothermal energy utilization and creates an immersive environment for people by unveiling physical phenomena during energy production. Through the exploitation of cutting-edge technology, *Thermal Stage* differs itself from those gigantic geo-power plants and acquires the capacity to engage people in an unexpected way.**

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What kind of artwork should be placed in such a desert that marks significant cultural activities? The initial idea is to not only propose a net-zero structure as a shelter but also creates a platform to showcase the power of natural energy.

The design is inspired by Fly Geyser. The discharge of water and steam celebrates the rich geothermal resources under this land. It is such an intriguing and site-specific element with the potential to produce clean energy and bridge the gap between untouchable technology and human perception. Derived from the form of Fly Geyser, Thermal Stage aims to become a part of the environment while exhibiting how art can coexist with tech.

The work is composed of two major parts: the TEG Ring Belt and the Central Tower. The Ring Belt sets the horizontal stage for public events upon Fly Reservoir. Underneath its semi-transparent surface is a circular grid of thermoelectirc generator (TEG) modules, which is the key component of geothermal energy harvesting. In the center of this stage, the double-layered Central Tower extends towards the sky, creating a cavity for steam condensation and water reuse. Visitors could gather together under this cavity to watch the artificial rainfall generated along with steam condensation. Water will be collected at the edge of the Central Tower and drained into the designed pond and buried tanks. Residents and visitors would take advantage of those water resources.

Electricity harvested is stored in underground batteries. A small portion of it will be used for on-site LED lighting system, and the rest can be stored in support of houses and camping sites’ demands.

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## **Technology Description**

Thermoelectric power generation technology harnesses the heat energy from geothermal sources and converts it directly into electricity by utilizing the “Seebeck effect” (or “thermoelectric effect”), which describes the phenomenon of generating electric current between two different materials both of whose sides are at different temperatures. It achieves the clean and green sustainable utilization of renewable geothermal energy.

The power generation system is designed and built using a series of an assembly of thermoelectric generator (TEG) modules that can be manufactured from many thermoelectric materials with extraordinary performance such as bismuth tellurite (Bi2Te3). Each of such TEG modules is placed between a heat source and a cold sink to create a temperature difference at the two ends of the TEG module. In the design of *Thermal Stage*, the steam flow, which is generated from vaporized liquid water passing over the hot rock in the earth at depth, can serve as the heat source, while the water at room temperature can serve as the cold sink. A partial generated power would be stored in portable batteries.

A thermosiphon heat exchanger (THE), which is extended into a geothermal region in the earth, can utilize the heat of hot rock from that region to vaporize water. Due to the density difference, the steam moves upwards and the water downwards in the THE under the ground. The generated steam transfers heat to one side of the TEG modules on the ground and is then condensed by liquid water, which is later returned to the hot geothermal region. Such design forms a self-supported circulation of heat transfer without the need of a mechanical pump and hence avoiding the use of moving parts in the system.

An air-cooled condensing (ACC) system can be used to condense a portion of the steam into liquid water. This clean water is collected in the condensate pond inside the design and can be used as potable water.

The TEG-based power system has many advantages such as compactness, lightweight, quietness, high reliability and scalability, and environmentally friendly operation. In addition, since the only single input of the system is heat from geothermal resources, it can be operated over any period of time throughout the year with minimal maintenance.

## **Environmental Impact Statement**

The limited availability of primary energy resources, increasing concern of environmental issues of emissions and the growing global demand for conserving energy continue to accelerate the search for technologies of generating electrical power. Thermoelectric power generators have now emerged as a promising alternative green technology owing to their potential to directly convert geothermal heat energy into electrical power. The application of this alternative green technology in converting heat energy into electrical power can improve the overall efficiencies of energy conversion systems.

The reason for consideration of using TEG to harvest geothermal resources is because of the simplicity of design and overall efficiency and power output of the design. Geothermal energy is very clean, is renewable, and allows for the elimination of fossil fuels in the power production process, which helps to reduce greenhouse gas emissions. *Thermal Stage* does NOT generate any physical or airborne waste byproducts during its operational life. In contrast, it sustainably harvests groundwater and geothermal energy, providing systems for the conservation and filtration of clean water used for cooling and generating steam. Due to the feature of silent operation of TEG, it is safe for people to view and interact with the art. Clean potable water can be generated by condensing the steam and collected inside the art. Thus, in addition to power generation, the art can also serve as a permanent shelter for tourists with basic life needs such as safe space, clean water, dry-food storage, and battery.

The structure of *Thermal Stage* is composed of environmentally-friendly materials including glass, steel, and concrete, and the TEG modules consist of non-toxic semiconductors. It is aimed to achieve zero usage of non-recyclable materials whenever possible in the design and construction process.

## **Primary Materials and Conceptual Cost Estimate**

1. *TEG system*
	1. One TEG assembly (contains 200 TEG modules):
		1. Single TEG module
			1. Thermoelectric materials: bismuth tellurite (Bi2Te3)
			2. Size: 4 cm x 4 cm x 0.5 cm
			3. Power: 1 W at a temperature difference of 70~80 ℃
			4. Unit price: $3.5
		2. Heat conducting media:
			1. Material: graphite sheets
			2. Size: 4 cm x 4 cm
			3. Unit price: $2.5
		3. Unit price per TEG assembly: ($3.5 + $2.5) x 200 = $1200
	2. Total cost of TEG system (contains 1500 TEG assemblies)
		1. $1200 x 1500 = $1,800,000
2. *Tempered glass*
	1. Unit price: $10 per square meter
	2. Total area: 10,000 m2
	3. Total cost: $10 x 10,000 = $100,000
3. *Frosted glass*
	1. Unit price: $10 per square meter
	2. Total area: 10,000 m2
	3. Total cost: $10 x 10,000 = $100,000
4. *Stainless steel tube*
	1. Unit price: $5 per meter
	2. Total length: 6,000 m
	3. Total cost: $5 x 6,000 = $30,000
5. *Thermosiphon heat exchanger*
	1. Total cost: $100,000
6. *Construction materials* (*concrete, steel, pipelines*)
	1. Total cost: $300,000
7. *Filter system*
	1. Total cost: $10,000
8. *Air cooled condensing system*
	1. Total cost: $30,000

Estimated total cost: $2,470,000 = 2.47 million

## **Annual kWh of Energy Expected**

The power of a single TEG module: 1 W.

The power of an assembly of TEG modules: 1 W x 200 = 200 W = 0.2 kW.

The total power of the TEG system: 0.2 kW x 1,500 = 300 kW = 0.3 MW.

The annual kWh of energy expected: 0.3 MW x 365 x 24 h = 2,628 MWh.

Estimated cost per watt: 8.23 USD/watt.

## **On-site Prototype Strategies**

## Realization of the TEG technology from lab test to industrial operation

1. Research of the model of the raw material TEG module and structure construction
2. Site survey of geothermal resources

Ref:

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[2] Gangjian Tan, Michihiro Ohta, and Mercouri G. Kanatzidis. "Thermoelectric power generation: from new materials to devices." *Philosophical Transactions of the Royal Society A* 377.2152 (2019): 20180450.

[3] Kewen Li, et al. "An expandable thermoelectric power generator and the experimental studies on power output." *International Journal of Heat and Mass Transfer* 160 (2020): 120205.

[4] Hayati Mamur, and Rasit AHISKA. "A review: Thermoelectric generators in renewable energy." *International Journal of Renewable Energy Research (IJRER)* 4.1 (2014): 128-136.