

Experimental Investigation of Geothermal Heat-Assisted Radiative Energy Harvesting for Day–Night Renewable Power Generation

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Abstract—The increasing demand for continuous, low-carbon electricity has created a need for renewable-energy technologies capable of operating beyond conventional daylight-dependent solar generation. This project proposes the experimental investigation of a hybrid energy-harvesting architecture that combines terrestrial/geothermal heat, thermoelectric or thermoradiative conversion, and sky-facing radiative cooling.

The proposed system uses heat available from the ground or a controlled low-grade geothermal source as the warm-side thermal reservoir. A high-infrared-emissivity radiator facing the sky acts as a thermal sink by emitting long-wave infrared radiation through the atmospheric transmission window, particularly around the 8–13 μm region. If a sufficient temperature difference can be established between the warm geothermal side and the radiatively cooled side, a thermoelectric generator can convert part of this temperature difference into electrical energy.

The initial experimental prototype will use a commercially available thermoelectric generator. A subsequent research stage may investigate semiconductor thermoradiative conversion. A spectrally selective radiator with low solar absorptance and high infrared emissivity will also be evaluated to determine whether operation can be extended into daytime.

The research will measure temperature difference, open-circuit voltage, current, electrical power, energy yield, environmental conditions and system stability during nighttime, daytime and continuous 24-hour operation.

The project does not assume commercially significant power generation in advance. Its primary purpose is to experimentally determine whether low-grade geothermal/terrestrial heat can maintain a useful thermal gradient against the radiative sky sink and to identify the engineering conditions required for practical energy harvesting.

Index Terms—Geothermal energy, radiative cooling, thermoelectric generation, thermoradiative conversion, night-sky cooling, atmospheric window, renewable energy.

I. PROJECT SYNOPSIS

1.1 Background

Conventional photovoltaic generation is strongly dependent on sunlight and therefore does not directly generate electricity during nighttime. Energy storage can overcome this limitation, but storage introduces additional cost, complexity, degradation and material requirements.

The Earth, however, continuously exchanges thermal energy with its surroundings. The atmosphere is relatively transparent to certain infrared wavelengths, particularly within the atmospheric transmission window around 8–13 μm . A specially designed surface can therefore radiate thermal energy toward the sky and, under favorable conditions, cool below ambient temperature.

This phenomenon is known as passive radiative cooling.

Separately, geothermal and terrestrial environments contain low-grade thermal energy that may remain available continuously. The proposed research explores whether these two phenomena can be combined.

The fundamental concept is:

Geothermal/Ground Heat $\rightarrow$ Warm Thermal Reservoir $\rightarrow$ Temperature Gradient $\rightarrow$ Thermoelectric/Thermoradiative Conversion $\rightarrow$ Electrical Energy

with the sky-facing radiator providing the cold-side thermal sink.

II. PROBLEM STATEMENT

Low-grade geothermal and terrestrial heat is widely available but may have a relatively small temperature difference compared with conventional high-temperature geothermal power systems.

At the same time, night-sky radiative cooling can provide a passive thermal sink, but the resulting temperature difference is strongly influenced by atmospheric conditions.

The proposed project therefore investigates the following fundamental question:

Can low-grade geothermal or terrestrial heat maintain a sufficiently large and stable temperature difference against a sky-facing radiative cooling surface to produce measurable and useful electrical energy?

A second research question is:

Can a spectrally selective radiator reduce daytime solar heating sufficiently to extend the operating period beyond nighttime?

III. RESEARCH GAP

Radiative cooling, geothermal energy conversion, thermoelectric generation and thermoradiative energy conversion have each been investigated in previous research.

Nighttime electricity generation using radiative cooling has also been studied, as have geothermal thermoelectric systems and daytime radiative-cooling/thermoelectric systems.

Therefore, the novelty of this proposal should **not** be claimed as simply:

- radiative cooling for electricity generation;
- geothermal electricity generation;
- thermoelectric generation; or
- daytime radiative cooling.

Instead, the proposed research investigates the integration and experimental characterization of:

Low-grade geothermal/terrestrial heat + sky radiative cooling + thermal-to-electric conversion + potential daytime spectral selectivity.

The research will determine whether this integrated architecture can produce repeatable electrical output and under what environmental and thermal conditions.

IV. AIM

To design, fabricate and experimentally evaluate a low-grade geothermal/terrestrial heat-assisted radiative energy-harvesting system capable of converting an experimentally established temperature difference between a warm ground/geothermal source and a sky-facing radiative thermal sink into electrical energy.

V. OBJECTIVES

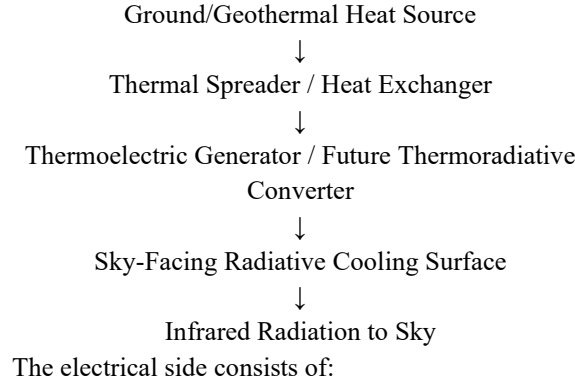
The project has the following objectives:

1. Design a laboratory-scale geothermal/radiative energy-harvesting prototype.
2. Use ground or controlled geothermal heat as the warm-side thermal source.
3. Develop a high-infrared-emissivity sky-facing radiator.
4. Establish and measure the temperature difference across a thermoelectric generator.
5. Measure open-circuit voltage, load voltage, current and electrical power.
6. Investigate nighttime radiative cooling under different atmospheric conditions.
7. Study the effects of ambient temperature, ground temperature, humidity, wind and cloud conditions.
8. Develop and test a low-solar-absorptance/high-infrared-emissivity radiator for daytime operation.
9. Conduct continuous 24-hour thermal and electrical measurements.
10. Develop a mathematical model of radiative, convective and conductive heat transfer.
11. Determine the conditions required for sustained measurable electrical output.
12. Develop a roadmap toward advanced thermoradiative semiconductor conversion.
13. Evaluate potential applications in remote and low-power electronic systems.
14. Generate experimental data suitable for academic publication and future technology-development proposals.

VI. PROPOSED SYSTEM ARCHITECTURE

6.1 Overall Architecture

The proposed system consists of:



TEG → Voltage/Current Measurement → Load or DC-DC Converter → Storage/Low-Power Device

Environmental sensors continuously monitor:

- Hot-side temperature
- Cold-side/radiator temperature
- Ambient temperature
- Humidity
- Wind speed
- Solar irradiance
- Cloud/sky conditions

Experimental Investigation of Geothermal Heat-Assisted Radiative Energy Harvesting for Day-Night Renewable Power Generation

Project Proposal

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1. Abstract

The increasing demand for continuous, low-carbon energy has created a need for renewable energy technologies capable of operating beyond conventional daylight-dependent solar generation. This project proposes the experimental investigation of a hybrid energy-harvesting system that combines terrestrial/geothermal heat, thermoelectric or thermoradiative conversion, and night-sky radiative cooling. The proposed system uses heat available from the ground or a low-grade geothermal source as the warm-side thermal reservoir. A sky-facing, high-infrared-emissivity radiator acts as a thermal sink by emitting long-wave infrared radiation through the atmospheric transmission window, particularly in the 8–13 μm region. The resulting temperature difference can potentially be converted into electrical power using a thermoelectric generator in the initial prototype. A future version may investigate semiconductor thermoradiative conversion. The research will experimentally evaluate the temperature gradient, open-circuit voltage, electrical power, energy yield, and stability of the system under nighttime and daytime atmospheric conditions. A spectrally selective radiator with low solar absorbance and high infrared emissivity will also be investigated for possible daytime operation. The study does not assume commercially significant power generation in advance. Instead, it aims to establish experimentally whether geothermal/terrestrial heat can sustain a useful thermal gradient against the sky radiative sink and determine the engineering conditions for continuous or extended day-night operation.

Keywords: Geothermal energy, radiative cooling, thermoelectric generation, thermoradiative conversion, night-sky cooling, renewable energy.

2. Project Synopsis

2.1 Background

Most renewable electricity technologies depend on solar availability. During nighttime, photovoltaic generation stops, creating a requirement for energy storage or alternative generation technologies. At the same time, the Earth's surface continuously exchanges thermal radiation with the atmosphere and outer space. Under suitable conditions, a properly designed surface can radiate thermal energy through the atmospheric infrared transmission window and cool below the ambient temperature (radiative cooling). The proposed research investigates whether this radiative cooling phenomenon can be combined with geothermal or terrestrial low-grade heat to establish a temperature difference that can be converted into electricity.

2.2 Problem Statement

Low-grade geothermal heat is widely available but difficult to convert efficiently into electricity when the temperature difference is small. Separately, night-sky radiative cooling can create a temperature difference between a radiative surface and its surroundings, and previous research has investigated nighttime electricity generation using this principle. However, the proposed project focuses on an integrated architecture in which ground/geothermal heat and sky radiation work together through a thermoelectric/thermoradiative system.

2.3 Research Gap

Radiative cooling, thermoelectric generation, geothermal energy conversion, and thermoradiative energy conversion have each been investigated independently. The proposed research investigates their integration and experimentally evaluates the performance under both nighttime and daytime conditions.

3. Objectives

1. Design a laboratory-scale prototype combining a terrestrial/geothermal heat source and a sky-facing radiative cooler.
2. Establish a measurable temperature difference across a thermoelectric generator.
3. Measure open-circuit voltage and electrical power under different thermal conditions.
4. Investigate nighttime radiative cooling performance.
5. Evaluate the effect of ground temperature, ambient temperature, humidity, cloud cover and wind.
6. Investigate a low-solar-absorbance/high-infrared-emissivity radiator for daytime operation.
7. Conduct continuous 24-hour thermal and electrical measurements.
8. Develop a mathematical model for heat transfer.
9. Determine conditions for sustained useful output.
10. Establish a roadmap toward a future thermoradiative semiconductor device.

4. Aim

To design, fabricate and experimentally evaluate a low-grade geothermal/terrestrial heat-assisted radiative energy-harvesting system capable of producing measurable electrical power through a temperature difference between a warm geothermal source and a sky-facing radiative thermal sink.

5. Proposed System Architecture and Working Principle

Night Operation

Day Operation

System Block Diagram & Circuit

Prototype Design (Cross-section)

Key Equations

Thermoelectric generation

$$V_{oc} = \alpha \Delta T$$

V_{oc} = open-circuit voltage
 α = Seebeck coefficient
 ΔT = temperature difference

Electrical power (approx.)

$$P_L = \frac{V_{oc}^2 R_L}{(R_L + R_i)^2}$$

R_L = load resistance
 R_i = internal resistance

Radiative heat transfer

$$Q_{rad} = \epsilon \sigma A (T_s^4 - T_{sky}^4)$$

ϵ = emissivity, σ = Stefan-Boltzmann constant
 A = area, T_s = radiator temperature
 T_{sky} = sky temperature

Experimental Methodology

1. Calibration – sensor and instrument calibration.
2. Laboratory Testing – controlled heat source, measure ΔT , V, I, power.
3. Night-Sky Testing – clear sky conditions, record thermal and electrical data.
4. Daytime Testing – evaluate selective radiator for solar rejection.
5. 24-Hour Testing – continuous operation and energy yield.

Bill of Materials (Indicative)

Item	Spec. / Qty.
TEG module (Bi ₂ Te ₃)	1
Aluminum/Copper plates	2
Radiative cooling surface	1
Selective day/IR radiator	1
Insulation (high-temp)	1
Temperature sensors (RTD)	2
Voltage & current sensor	1 set
Data logger (microcontroller)	1 set
Environmental sensors	1 set
Variable load / DC-DC	1
Mounting hardware	1 set

6. Expected Outcomes

- ✓ Geothermal/radiative energy data and temperature gradients.
- ✓ Electrical output characteristics and energy yield.
- ✓ Comparison of day vs. night performance.
- ✓ 24-hour operating feasibility.
- ✓ Design recommendations and validated model.

7. Applications

- Remote sensors and IoT devices
- Geothermal-sink monitoring
- Environmental monitoring stations
- Autonomous instrumentation
- Low-power systems
- Hybrid renewable-energy systems

8. TRL Roadmap

1. Concept & Literature Review
2. Laboratory Prototype
3. Night-Sky Testing
4. Geothermal/Heat Source Testing
5. Daytime Selective Radiator Testing
6. 24-Hour Operation
7. Field Testing & Optimization
8. Advanced Thermoradiative Converter Technology Demonstration

9. Conclusion

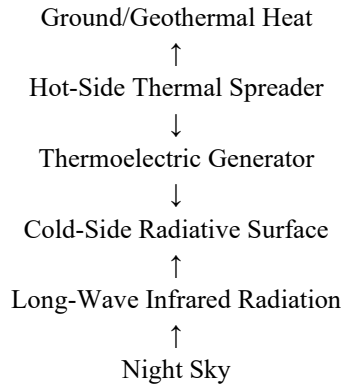
This project provides a structured pathway to investigate whether geothermal/terrestrial heat can maintain a useful thermal gradient against a radiative sky sink for electrical energy generation. The results will inform the technical feasibility, design improvements and future development of a continuous, low-carbon energy system.

VII. PICTORIAL REPRESENTATION

Figure 1 – Proposed Day–Night Energy-Harvesting Architecture

The proposed pictorial representation illustrates two operating conditions.

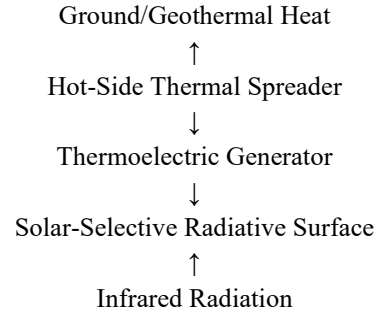
Night Operation



During nighttime, the radiator is designed to emit infrared radiation toward the sky. If the radiator

becomes sufficiently cooler than the geothermal/ground-supported hot side, a temperature gradient develops across the thermoelectric generator.

Day Operation



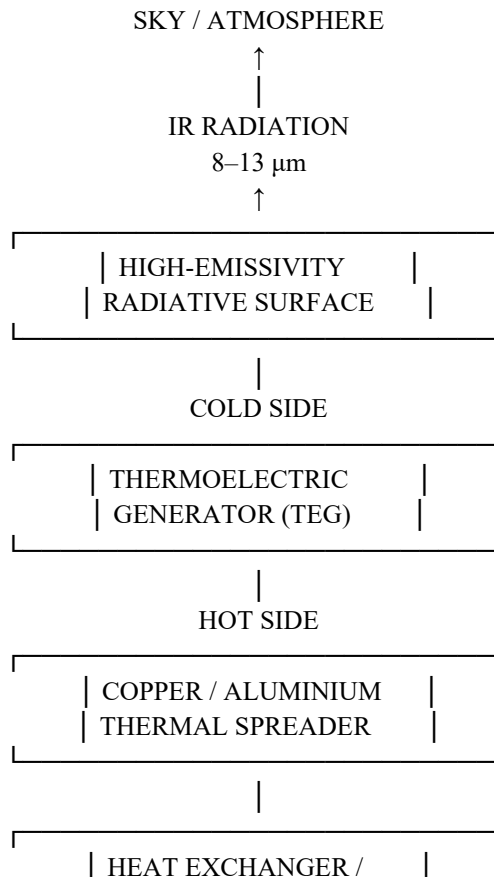
At the same time:

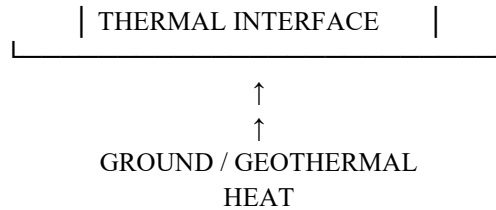
Sunlight → Highly Reflective/Solar-Rejecting Surface

The daytime design attempts to minimize solar absorption while retaining high thermal-infrared emissivity.

VIII. PROTOTYPE CROSS-SECTION

The proposed physical prototype can be represented as:

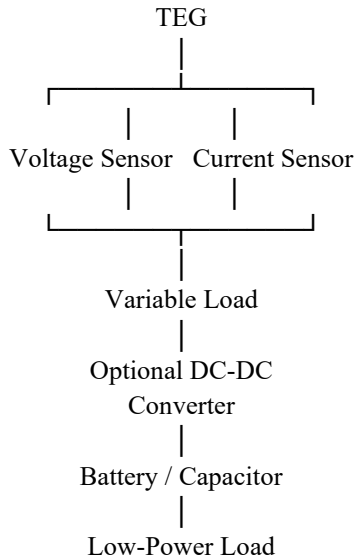




The supporting structure should be thermally insulated so that heat reaches the intended conversion path rather than bypassing the thermoelectric device through parasitic conduction.

IX. ELECTRICAL SYSTEM

The electrical system will initially consist of:



The initial experiment should measure the raw electrical output before adding complex power electronics.

X. PHYSICAL PRINCIPLE

10.1 Radiative Heat Transfer

The simplified net radiative heat-transfer relationship is:

$$Q_{rad} = \epsilon \sigma A (T_r^4 - T_{sky}^4)$$

where:

- Q_{rad} = radiative heat transfer
- ϵ = radiator emissivity
- σ = Stefan-Boltzmann constant
- A = radiator area
- T_r = radiator temperature
- T_{sky} = effective radiative sky temperature.

The actual system will also experience convection, conduction and solar absorption.

Therefore:

$$Q_{net} = Q_{rad} - Q_{solar} - Q_{conv} - Q_{cond}$$

This is particularly important for daytime operation.

XI. THERMOELECTRIC CONVERSION

For the initial prototype:

$$V_{oc} = \alpha \Delta T$$

where:

- V_{oc} = open-circuit voltage
- α = effective Seebeck coefficient
- ΔT = temperature difference across the TEG.

The electrical power delivered to a load can approximately be expressed as:

$$P_L = \frac{V_{oc}^2 R_L}{(R_i + R_L)^2}$$

where:

- R_L = external load resistance
- R_i = internal resistance of the generator.

Maximum power occurs approximately when:

$$R_L \approx R_i$$

subject to the actual TEG's temperature-dependent electrical characteristics.

XII. DAYTIME OPERATION

Daytime operation is one of the major experimental challenges.

A conventional dark radiative surface can absorb substantial solar radiation, potentially heating the radiator rather than cooling it.

Therefore, the proposed daytime radiator should aim for:

Low solar absorptance

$$\alpha_{solar} \rightarrow \text{low}$$

and

High infrared emissivity

$$\epsilon_{IR} \rightarrow \text{high}$$

The research will investigate whether such spectral selectivity can maintain a useful thermal gradient while exposed to sunlight.

Daytime performance will therefore be treated as an experimental question rather than an assumed operating condition.

XIII. BILL OF MATERIALS

Component	Indicative specification
Thermoelectric module	Commercial Bi ₂ Te ₃ TEG
Hot-side plate	Aluminium/copper
Cold-side plate	Aluminium/copper
Radiative surface	High-IR-emissivity coating/material
Daytime radiator	Low-solar-absorptance/high-IR-emissivity surface
Thermal insulation	Low-conductivity insulation
Heat exchanger	Ground/geothermal thermal interface
Temperature sensors	PT100/RTD or calibrated thermocouples
Voltage sensor	Precision voltage measurement
Current sensor	Precision current measurement
Data logger	Microcontroller/data acquisition system
Humidity sensor	Environmental sensor
Wind sensor	Anemometer
Solar sensor	Pyranometer/irradiance sensor
Variable load	Precision resistor/electronic load
DC-DC converter	Optional power-conditioning stage
Battery/capacitor	Optional energy storage
Mounting structure	Weather-resistant frame
Thermal interface	Thermal paste/pad
Weather enclosure	Sensor/electronics protection

XIV. EXPERIMENTAL METHODOLOGY

Phase 1 – Sensor Calibration

All temperature, voltage, current and environmental sensors will be calibrated.

Measurements will be cross-checked against reference instruments wherever possible.

Phase 2 – Controlled Laboratory Experiment

Before using an actual geothermal site, a controlled thermal source will simulate the ground/geothermal condition.

Different hot-side temperatures will be investigated.

Measurements:

- Hot-side temperature
- Cold-side temperature
- Temperature difference
- Ambient temperature
- Open-circuit voltage
- Load voltage
- Load current
- Electrical power

Phase 3 – Night-Sky Experiment

The radiator will be exposed to an unobstructed sky during nighttime.

Data will include:

- Radiator temperature
- Hot-side temperature
- Ambient temperature
- Temperature difference
- Voltage
- Current
- Power
- Humidity
- Wind speed
- Cloud condition.

Clear-sky and cloudy-sky conditions should be compared whenever practical.

Phase 4 – Daytime Experiment

The daytime selective radiator will be tested under sunlight.

The following parameters will be compared:

- Solar irradiance
- Radiator temperature
- Ambient temperature

- Hot-side temperature
- Temperature gradient
- Electrical output.

The purpose is to determine whether solar rejection can preserve radiative cooling sufficiently for useful operation.

Phase 5 – 24-Hour Experiment

The complete system will be operated continuously for at least 24 hours.

The principal energy metric will be:

$$E_{24h} = \int_0^{24h} P(t) dt$$

This provides a more meaningful measure of performance than simply reporting the highest instantaneous voltage.

XV. PERFORMANCE PARAMETERS

The following parameters will be calculated:

Temperature Difference

$$\Delta T = T_{hot} - T_{cold}$$

Open-Circuit Voltage

$$V_{oc}$$

Electrical Power

$$P = VI$$

Power Density

$$P_d = \frac{P_{max}}{A}$$

where A is the active generator/radiator area as defined for the experiment.

Daily Energy

$$E_{day} = \int P(t) dt$$

Stability

Temporal variation of:

- Temperature
- Voltage
- Current
- Power.

XVI. EXPERIMENTAL VARIABLES

Independent Variables

- Ground/geothermal temperature
- Ambient temperature
- Radiator emissivity
- Radiator solar absorptance

- Radiator area
- Atmospheric humidity
- Wind speed
- Solar irradiance
- Cloud conditions.

Dependent Variables

- Temperature difference
- Open-circuit voltage
- Current
- Electrical power
- Energy generated
- Operating duration.

Controlled Variables

Where possible:

- TEG type
- Electrical load
- Thermal interface
- Measurement interval
- Sensor position
- Radiator orientation
- Mounting configuration.

XVII. EXPECTED RESULTS

The project is expected to establish experimentally:

1. Whether a measurable geothermal/radiative temperature gradient can be produced.
2. The relationship between temperature gradient and electrical output.
3. The effect of atmospheric conditions on nighttime operation.
4. The effect of solar radiation on daytime operation.
5. The effectiveness of a selective radiator.
6. The maximum experimentally measured electrical power.
7. The accumulated energy over a 24-hour period.
8. The duration for which positive usable electrical output can be maintained.
9. The principal thermal losses.
10. The design modifications required for a higher-performance prototype.

No numerical output should be presented as a confirmed result until actual experiments have been completed.

XVIII. EXPECTED RESEARCH CONTRIBUTION

The project can contribute experimental knowledge regarding the integration of:

Low-grade terrestrial/geothermal heat with

sky-facing radiative cooling

and

thermal-to-electric conversion.

The study may provide a foundation for future work involving:

- advanced selective radiators;
- optimized heat exchangers;
- thermoelectric materials;
- thermoradiative semiconductor devices;
- thermal-energy management;
- autonomous low-power systems.

XIX. POTENTIAL APPLICATIONS

If adequate electrical output and long-term reliability are demonstrated, possible applications include:

19.1 Remote Sensors

Autonomous temperature, humidity and environmental sensors.

19.2 Geothermal Monitoring

Low-power monitoring equipment at geothermal locations.

19.3 IoT Devices

Low-power wireless monitoring systems.

19.4 Environmental Stations

Remote scientific instruments where battery replacement is difficult.

19.5 Remote Telemetry

Low-power data transmission systems.

20.6 Hybrid Renewable Systems

Integration with solar, thermal and energy-storage systems.

19.7 Scientific Instrumentation

Small autonomous instruments requiring continuous low-power energy.

XX. LIMITATIONS AND ENGINEERING RISKS

The proposed system faces several technical challenges.

20.1 Small Temperature Difference

The primary challenge may be obtaining a sufficiently large temperature gradient.

20.2 Atmospheric Conditions

Humidity, clouds and atmospheric water vapor can reduce radiative cooling performance.

20.3 Wind

Convective heat transfer may warm the radiator and reduce the temperature difference.

20.4 Daytime Solar Absorption

Solar radiation can significantly reduce or reverse the cooling effect.

20.5 Thermal Parasitic Losses

Heat may bypass the TEG through mechanical supports, wires or other conductive paths.

20.6 TEG Efficiency

Commercial TEGs may have limited efficiency at very small temperature differences.

20.7 Thermoradiative Device Complexity

A practical semiconductor thermoradiative converter may require specialized materials, fabrication and characterization facilities.

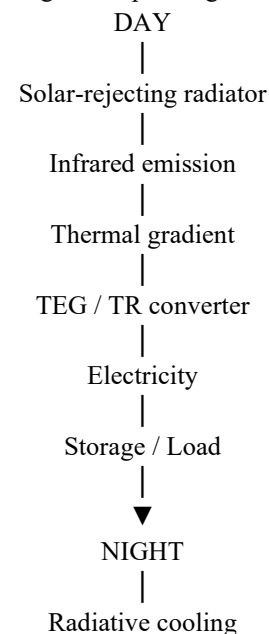
20.8 Geothermal Resource Variability

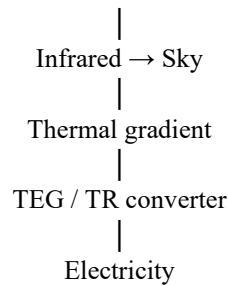
Actual geothermal conditions vary significantly between locations.

These limitations are part of the research problem and will be experimentally characterized.

XXI. 24-HOUR OPERATING CONCEPT

The proposed long-term operating concept is:





The experiment will determine whether this theoretical day–night operating cycle can actually be sustained.

XXII. TECHNOLOGY READINESS ROADMAP

Stage	Target
TRL 1–2	Concept and fundamental literature
TRL 2–3	Thermal/electrical modelling
TRL 3	Laboratory proof-of-concept
TRL 4	Outdoor nighttime prototype
TRL 4–5	Daytime selective-radiator testing
TRL 5	24-hour outdoor demonstration
TRL 5–6	Geothermal/ground-field validation
TRL 6	Optimized prototype
TRL 6–7	Advanced converter/radiator demonstration
TRL 7+	Long-duration application-specific demonstration

XXIII. FUTURE DEVELOPMENT

Following successful experimental validation, future research may focus on:

1. Larger radiative surfaces.
2. Improved thermal isolation.
3. Advanced infrared coatings.
4. Spectrally selective radiators.
5. Improved thermoelectric materials.
6. Advanced heat-exchanger designs.
7. Power-management electronics.
8. Energy storage.
9. IoT integration.
10. Semiconductor thermoradiative converters.

11. Field testing at suitable geothermal locations.
12. Long-duration reliability testing.

XXIV. PATENT AND PRIOR-ART CONSIDERATIONS

The project should not initially claim broad ownership over radiative cooling, geothermal energy or thermoelectric generation because these areas already contain substantial prior art.

Before filing any patent, a dedicated search should investigate combinations such as:

- geothermal + thermoradiative;
- geothermal + radiative cooling + thermoelectric;
- geothermal heat + infrared radiation + electricity;
- ground heat + night-sky radiation + generator;
- thermoradiative generator + geothermal;
- low-grade heat + radiative sky + electricity;
- geothermal + selective infrared emitter;
- geothermal + radiative cooling + thermoelectric generator.

Potential intellectual-property differentiation could arise from a specific:

- radiator architecture;
- thermal interface;
- heat-exchanger configuration;
- multilayer selective surface;
- day/night operating strategy;
- thermal-control mechanism;
- power-management architecture;
- integrated geothermal/radiative conversion system.

A formal patent search using Google Patents, WIPO PATENTSCOPE, Espacenet and Indian Patent Office records should be completed before making a patentability claim.

XXV. ACADEMIC NOVELTY POSITION

The appropriate research claim is:

Although radiative cooling-based nighttime electricity generation, thermoelectric energy harvesting, geothermal energy conversion and thermoradiative energy conversion have been investigated independently and in several combinations, this project proposes an experimental investigation of their integration into a geothermal-assisted radiative energy-harvesting **architecture and evaluates its**

feasibility under both nocturnal and daytime atmospheric conditions.

This wording avoids claiming that the individual technologies are new.

XXVI. PROJECT DELIVERABLES

The project is expected to produce:

Deliverable 1

Thermal and electrical design of the prototype.

Deliverable 2

Laboratory prototype.

Deliverable 3

Night-sky experimental dataset.

Deliverable 4

Daytime selective-radiator dataset.

Deliverable 5

24-hour performance dataset.

Deliverable 6

Validated thermal/electrical model.

Deliverable 7

Prototype optimization report.

Deliverable 8

Technical research paper.

Deliverable 9

Future patent/prior-art assessment.

Deliverable 10

Technology-development roadmap.

XXVII. PROPOSED PROJECT PHASES

Phase	Activity
Phase 1	Literature review
Phase 2	Thermal modelling
Phase 3	Prototype design
Phase 4	Component procurement
Phase 5	Prototype fabrication
Phase 6	Sensor calibration
Phase 7	Laboratory testing
Phase 8	Night-sky testing
Phase 9	Daytime radiator testing
Phase 10	24-hour testing
Phase 11	Data analysis
Phase 12	Prototype optimization
Phase 13	Field validation
Phase 14	Research publication/patent assessment

XXVIII. SUCCESS CRITERIA

The project should be considered scientifically successful if it can establish, through measured data:

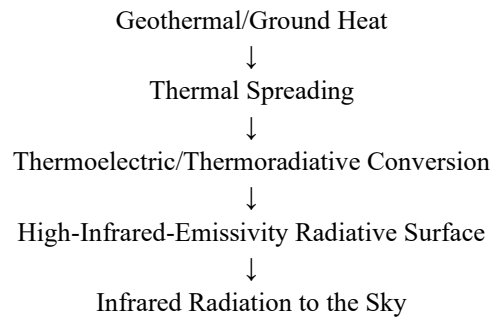
1. A repeatable temperature difference between the geothermal/ground side and radiative side.
2. A measurable electrical response corresponding to that temperature difference.
3. A quantified relationship between environmental conditions and electrical output.
4. A measured nighttime performance profile.
5. A measured daytime performance profile.
6. A complete 24-hour energy balance.
7. Identification of the dominant thermal losses.
8. A validated model capable of predicting experimental trends.
9. Clearly defined engineering requirements for the next prototype.

The objective is therefore experimental validation and characterization, not predetermined proof of commercial viability.

XXIX. CONCLUSION

This project proposes a novel experimental pathway for investigating whether low-grade geothermal or terrestrial heat can be coupled with sky-facing radiative cooling to create a persistent temperature gradient for electrical energy harvesting.

The core concept combines:



The proposed research further investigates whether a solar-rejecting, infrared-emitting surface can extend the operating period into daytime.

The initial prototype will employ a commercial thermoelectric generator because it provides a practical and accessible method for experimentally establishing the thermal-to-electrical behavior. Once the fundamental concept is characterized, future research can investigate more advanced thermoradiative semiconductor technologies.

The project's primary contribution will be experimental evidence determining whether the proposed thermal architecture can maintain a useful temperature difference, how much electrical energy can actually be obtained, what atmospheric conditions control performance, and what engineering improvements are required for future development.

The project therefore provides a structured pathway from:

Concept → Laboratory Prototype → Night-Sky Testing → Daytime Selective Radiator → 24-Hour Demonstration → Geothermal Field Testing → Advanced Thermoradiative Converter.

ACKNOWLEDGMENT / AI-ASSISTANCE DISCLOSURE

The proposal structure, technical language and literature-oriented drafting were prepared with AI-assisted writing and research support. The proposed experimental methodology, calculations, prototype specifications and future results must be independently verified by the researcher. No experimental results should be represented as measured data until the experiments have been conducted.

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PROPOSED PROJECT TITLE FOR FORMAL SUBMISSION

Experimental Investigation of Geothermal Heat-Assisted Radiative Energy Harvesting for Day–Night Renewable Power Generation

Short Technical Name

Geothermal–Radiative Energy Harvester (G-REH)

Core Research Concept

"Using low-grade terrestrial/geothermal heat as the warm-side energy source and the sky as a radiative thermal sink for continuous or extended day–night thermal energy harvesting."