



CASCADe 2027 NON-CONFIDENTIAL SUMMARY »

Battery-Free Tree Sensors for Power Line Wildfire Prevention

Overview

Overgrown tree crowns that contact overhead power lines are a leading cause of utility-linked wildfires, yet most electric utilities and forest landowners still rely on infrequent visual inspections, satellite imagery, or LiDAR surveys that miss fast-changing conditions between assessments. Researchers at the University of Washington Tacoma and the Federal University of Paraíba have developed a self-powered sensor system that embeds directly into a tree trunk and infers crown size from internal and external temperature patterns, without cameras, aerial surveys, or batteries. The system harvests its own operating power from the natural temperature difference between the inside and outside of the tree, then wirelessly transmits crown-size and early-fire-risk data to utility operators or emergency services through existing communication infrastructure such as transmission towers, satellites, or aerial drones.

- **Problem:** Vegetation-caused power line fires are costly and difficult to predict using current periodic, low-resolution monitoring methods.
- **Solution:** A battery-free, embeddable sensor that continuously infers tree crown size and detects abnormal temperature spikes indicative of early fire risk.
- **Impact:** Enables continuous, individual-tree monitoring across large forested transmission corridors without the cost and logistics of manual inspection or recurring battery replacement.

Description

The system is a crown size monitoring device that is at least partially embedded within a tree trunk. A metal rod containing one or more temperature sensors is inserted into the trunk at varying depths, while an additional sensor measures external (ambient) trunk temperature. A thermoelectric generator captures the temperature differential between the internal and external readings via the Seebeck effect, and a rectifier and step-up converter condition this harvested voltage to power the sensor system and a radiofrequency transmitter/receiver, eliminating the need for batteries or solar panels. A microcontroller aggregates the temperature readings over a 24-hour cycle into a temperature pattern; because a larger tree crown affects shading, transpiration, heat absorption, and airflow, the resulting temperature pattern can be mapped to an estimated crown size using a look-up table, a heuristic model, a thermodynamic energy-balance model, or a machine learning model (e.g., decision tree, random forest, gradient boosting, or neural network).

COMOTION REFERENCE »

BDP 9077

INNOVATION MANAGER »

Judy Bridges

SECTOR »

Clean Tech

LEAD INVESTIGATORS »

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The determined crown size is transmitted to a local receiver — for example, mounted on an electrical transmission tower — and relayed onward to a utility company or forestry operator via satellite or other long-range communication systems, allowing the utility to schedule vegetation maintenance (trimming or pruning) before a crown grows into contact with a power line. The same embedded sensor also monitors ambient temperature for sudden spikes that may indicate a nearby fire, enabling a secondary early-fire-detection alert to emergency services. A related concept extends this architecture to a distributed network of sensor-embedded "smart trees" that relay environmental and fire-risk data tree-to-tree and ultimately to a nanosatellite or aerial-drone relay for use in monitoring larger, more remote forest areas.

Modality: Environmental/industrial IoT hardware with an embedded machine learning and thermodynamic modeling layer (Physical Sciences / Hardware technology). **Workflow:** Internal/external temperature sensing -> thermoelectric energy harvesting and power conditioning -> on-device temperature pattern generation -> crown-size and fire-risk inference -> wireless relay to utility or emergency-services computing systems. Supporting evidence includes an issued PCT patent application with full claims and prototype figures, an earlier peer-reviewed computational model of tree trunk temperature distribution (An et al., 2020 IEEE), and field-deployed thermoelectric generator hardware tested on trees in the Tacoma, WA area and in the Azores Archipelago, Portugal.

Technology Readiness Level (TRL)

TRL 4 — System or subsystem components tested in a laboratory environment. Prototype thermoelectric-generator/sensor rods have been fabricated and field-installed on individual trees, and the temperature-to-crown-size inference approach (look-up table, heuristic, and machine learning models) has been developed and described in a filed patent application, supported by earlier computational modeling and laboratory/outdoor testing of the underlying thermoelectric energy harvesting hardware. Full-scale, multi-tree deployment in an operational utility or forestry environment, and independent validation of the crown-size correlation against ground-truth measurements, have not yet been completed.

Value Proposition

- Eliminates the need for costly, infrequent manual crew inspections, which utilities currently perform only about four times per year on transmission lines and once every two years on distribution lines.
- Battery-free operation via thermoelectric energy harvesting removes the recurring cost, environmental impact, and logistical burden of replacing batteries across thousands of remote, hard-to-access forest sensors.
- Provides continuous, individual-tree, real-time data that complements the low temporal and spatial resolution of satellite imagery and LiDAR scans currently used by utilities and land managers.
- Dual-purpose design supports both proactive vegetation-management scheduling (crown-growth alerts) and early wildfire detection (ambient temperature anomaly alerts) from the same low-cost device.
- Scalable, low-infrastructure architecture leverages existing transmission towers, satellites, or aerial drones for data relay, reducing the need for new communication buildout in remote forests.

Intellectual Property Position

[WO2026173910](#) - Patent application pending.

Market Opportunity

- Target customers include electric utility companies responsible for transmission and distribution vegetation management, as well as large timberland and forestry operators managing power line corridors through their land.
- Internal market estimates cited by the research team indicate the U.S. electric power industry incurred approximately \$92.8 billion in wildfire-related costs in 2023, with costs projected to reach approximately \$187.9 billion by 2033.
- Approximately 30 million acres of forest are estimated to burn annually in the United States, with roughly 20% of related fires attributed to power line contact, according to figures cited in program materials.
- Early go-to-market conversations and interview outreach have been initiated with prospective customers and pilot partners, including a major U.S. timberland company, a Pacific Northwest municipal electric utility, and Brazilian utility, forestry, and firefighting organizations, though documented interview findings were not available at the time of this profile.
- Current incumbent monitoring approaches (LiDAR surveys, satellite imagery, and periodic visual crew inspection) provide infrequent, low-resolution assessments, creating an opening for a continuous, tree-level monitoring layer that can validate and supplement existing utility vegetation-management workflows.

References

1. C. P. Souza, F. B. S. Carvalho, F. A. N. Silva, H. A. Andrade, N. de V. Silva, O. Baiocchi, I. Müller, "On Harvesting Energy from Tree Trunks for Environmental Monitoring," *International Journal of Distributed Sensor Networks*, 2016, 12(6). <https://doi.org/10.1155/2016/9383765>
2. Y. An, O. Baiocchi, M. Hockman, S. Teng, "Computational Model for Temperature in Tree Trunk for Energy Harvesting," 2020 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), 2020, pp. 1-6.
3. Y. An, O. Baiocchi, H. E. Dillon, C. P. de Souza, Y. Qiu, "Regression Model for Tree Trunk Temperature for Energy Harvesting," 2024 IEEE Conference on Technologies for Sustainability (SusTech), Portland, OR, 2024, pp. 237-244. <https://doi.org/10.1109/SusTech60925.2024.10553484>
4. "Using Trees as a Natural Weather Station for Wind Pattern Forecasting Applied to Forest Firefighting," *Sensors*, 2025, 25(23), 7205. <https://doi.org/10.3390/s25237205>
5. C. P. de Souza and O. Baiocchi, "Energy Resources in Agriculture and Forestry: How to be Prepared for the Internet of Things (IoT) Revolution," *Energy Systems and Environment*, InTech, 2018. <https://doi.org/10.5772/intechopen.74940>