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PV System with Wind Loading Mitigation Features

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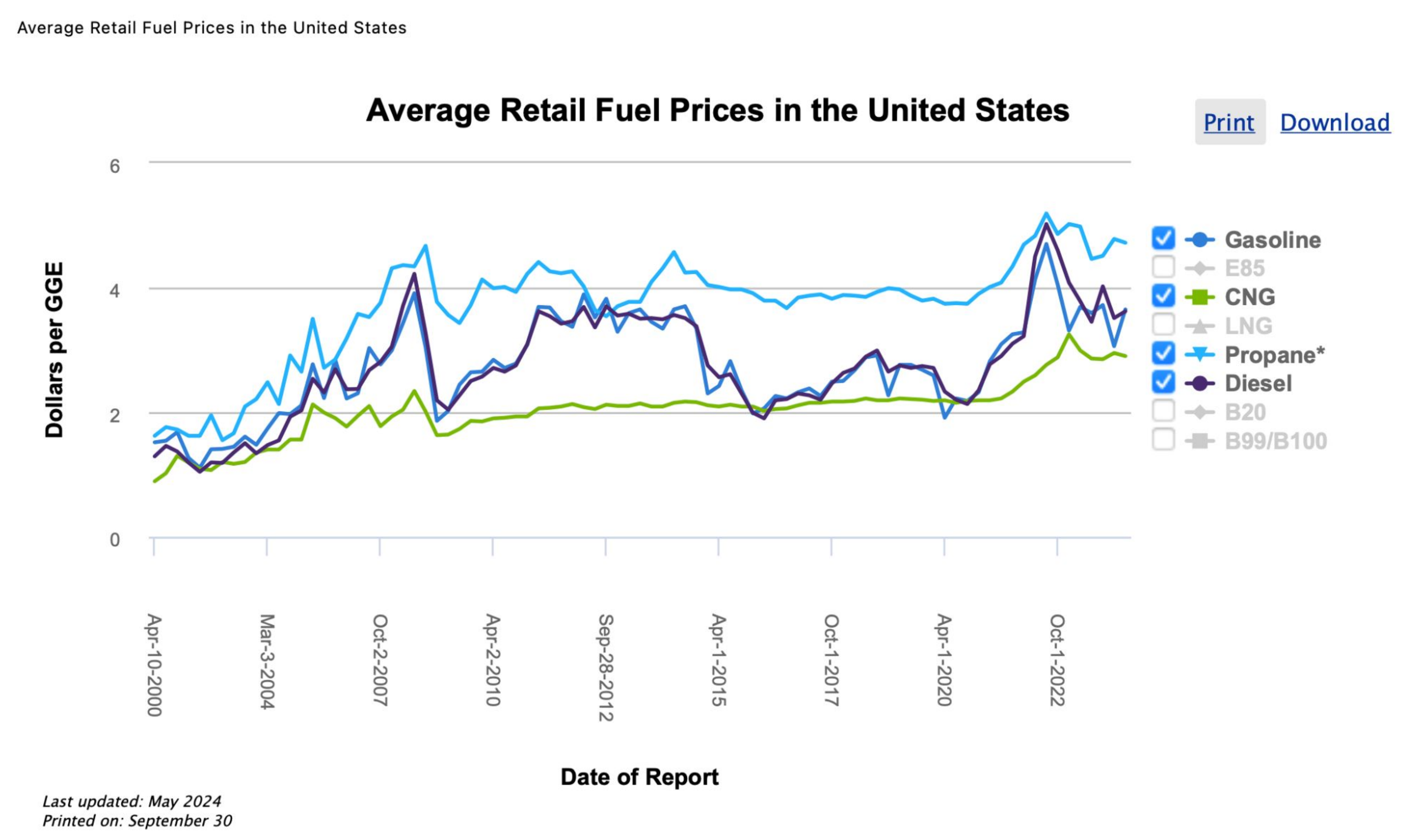
Problem Statement

Electricity is a fundamental utility for modern life—powering lighting, HVAC systems, communication, education, and entertainment. Extending access to reliable electricity in remote and underserved areas is a mission worth pursuing. In many parts of rural America and developing nations, centralized power grids remain inaccessible, leaving millions without dependable energy.

To meet the growing global demand for clean, sustainable power—and to support international efforts to reduce CO_2 emissions—there is an urgent need for off-grid solutions that are both effective and environmentally responsible. Fossil fuel-based generators, often used in these communities, are expensive, polluting, and susceptible to supply chain disruptions.

With the ongoing shift toward renewable energy, this capstone project from Group 33 developed a portable photovoltaic (PV) system capable of supplying clean electricity to off-grid communities. Uniquely, the system features wind mitigation capabilities to maintain performance and structural integrity in adverse weather conditions. By doing so, the solution provides a vital energy resource for underserved populations, disaster relief operations, and areas prone to extreme environmental conditions—contributing to both social impact and environmental sustainability.



Concept and Theory

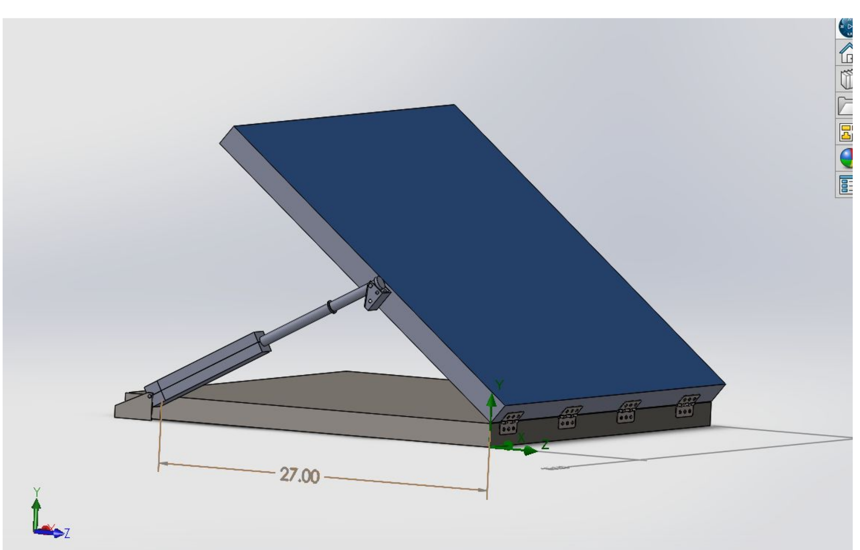
This project centers on the development of a portable photovoltaic (PV) system designed to address the dual challenges of energy accessibility and environmental resilience. At its core, the concept integrates solar energy generation with innovative wind-loading mitigation features, enabling reliable operation in regions prone to extreme weather conditions. The system is intended to serve off-grid communities, disaster relief operations, and remote installations by providing a modular, scalable, and autonomous energy solution.

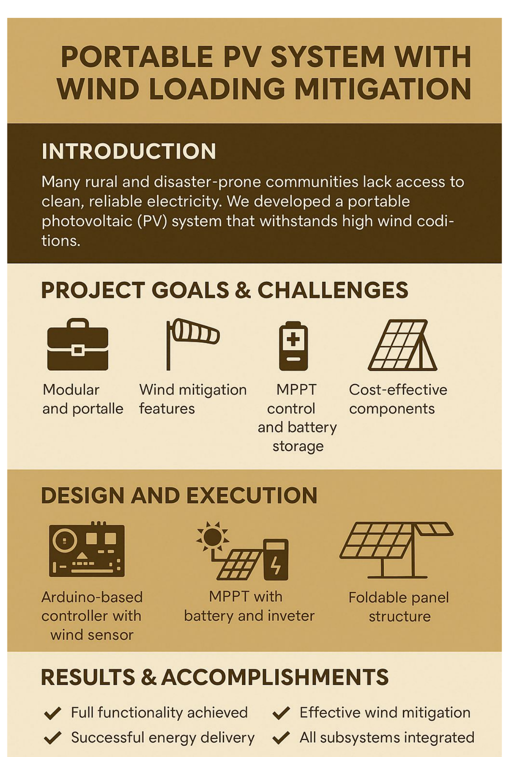
Theoretical foundations draw from renewable energy technologies, structural dynamics, and control systems. Using advanced simulation tools—such as Computational Fluid Dynamics (CFD), Finite Element Analysis (FEA), electrical system modeling, and control algorithm design—we aim to optimize performance, maximize efficiency, and ensure mechanical stability. Our goal is to deliver a sustainable, high-efficiency energy system that is both technically robust and economically viable for underserved or vulnerable populations.

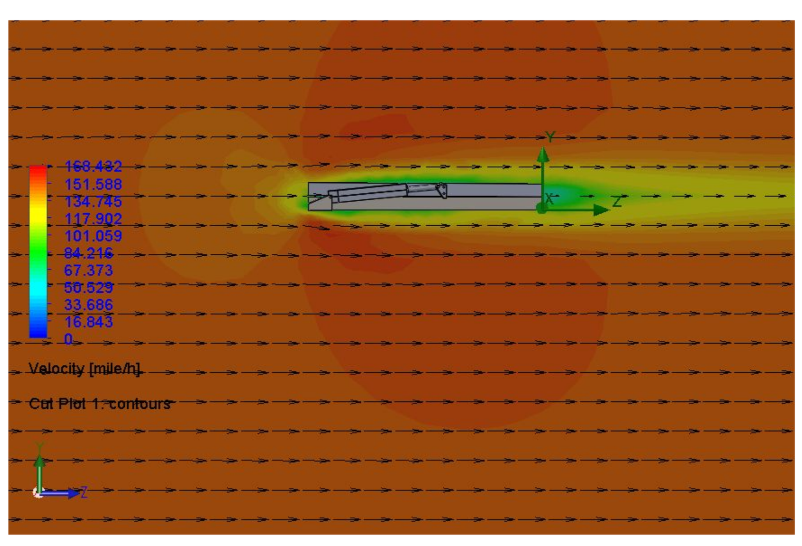
Results

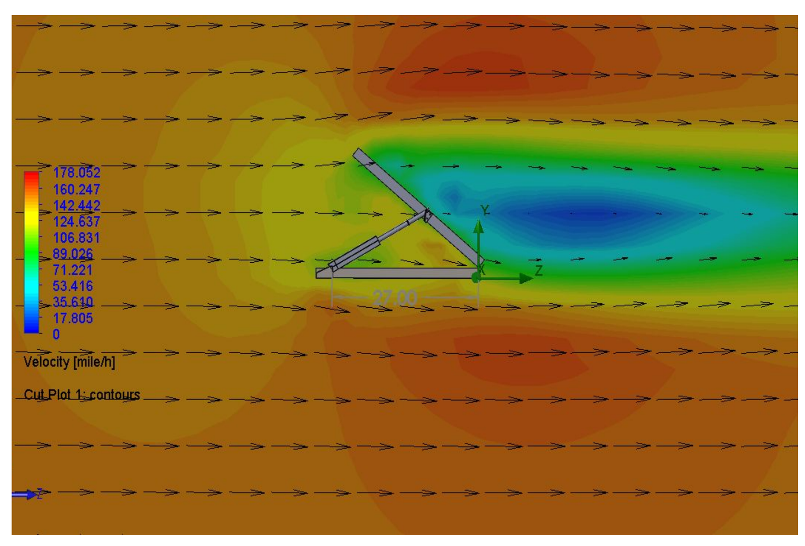
Our project demonstrates a high-performance, efficient solar system designed with wind mitigation features, enabling deployment in regions vulnerable to extreme weather. Simulation results show significantly higher efficiency than typical portable systems, with optimized MPPT control, battery management, and inverter operation—reducing the required panel area for a given output. The system's robust architecture ensures high reliability and uptime through redundancy and fault detection. Economic analysis reveals a three-year payback period, accounting for reduced fuel use, lower maintenance, and initial system cost.

To reduce environmental impact and optimize resources, we employed a development strategy that combined comprehensive simulations with targeted physical prototyping. This allowed for broad validation across various conditions while minimizing material waste.









Conclusions

As global demand for clean, reliable energy grows, addressing energy access in underserved and off-grid communities remains a critical challenge. Team-33's portable photovoltaic (PV) system offers a meaningful solution by combining renewable energy generation with innovative wind mitigation features that enhance durability and system longevity in harsh environments.

Designed to operate independently of centralized power grids, this system supports deployment in remote areas, disaster zones, and other off-grid scenarios. Its modular, scalable design allows flexibility based on user needs, while its portability ensures ease of transport and setup. A key innovation is the system's automatic "stow mode," which reduces wind loading by 60%, significantly enhancing structural resilience during extreme weather events.