Hybrid VAWT & Solar Tracker

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Introduction

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Global renewable energy capacity increased by 9% in 2022, but intermittency remains a major barrier to reliability.

(Source: IEA, 2023)

The Growing Role of Renewables — and the Reliability Gap

Global renewable
energy capacity grew by **9% in 2022, 3,370 GW** worldwide

Solar PV and Wind
90% of global renewable growth in 2022. Governments targeting **Net Zero by 2050**

Solar Power
Only generates during daylight. 12-14 hrs max/day

Wind Power
Unpredictable and site-dependent. Can be zero for days

Power Shortage
Disasters cause 80–90% of outages, cutting power to field hospitals and emergency teams

Hybrid Solutions
Hybrid portable systems combine sources and enable rapid deployment for critical power.

Who Needs Reliable Off-Grid Power?

Intermittent renewables leave critical and remote operations vulnerable to power shortages.

Aerial view of a field hospital deployed during the 2010 Haiti earthquake, illustrating the scale and complexity of emergency medical operations in disaster zones. (Bar-On et al., 2011)

Disaster Zones

Field hospitals, emergency shelters, and rescue operations cannot rely on grid during disasters.

Remote Location

Remote off-grid sites often have no access to stable infrastructure diesel or no power solutions.

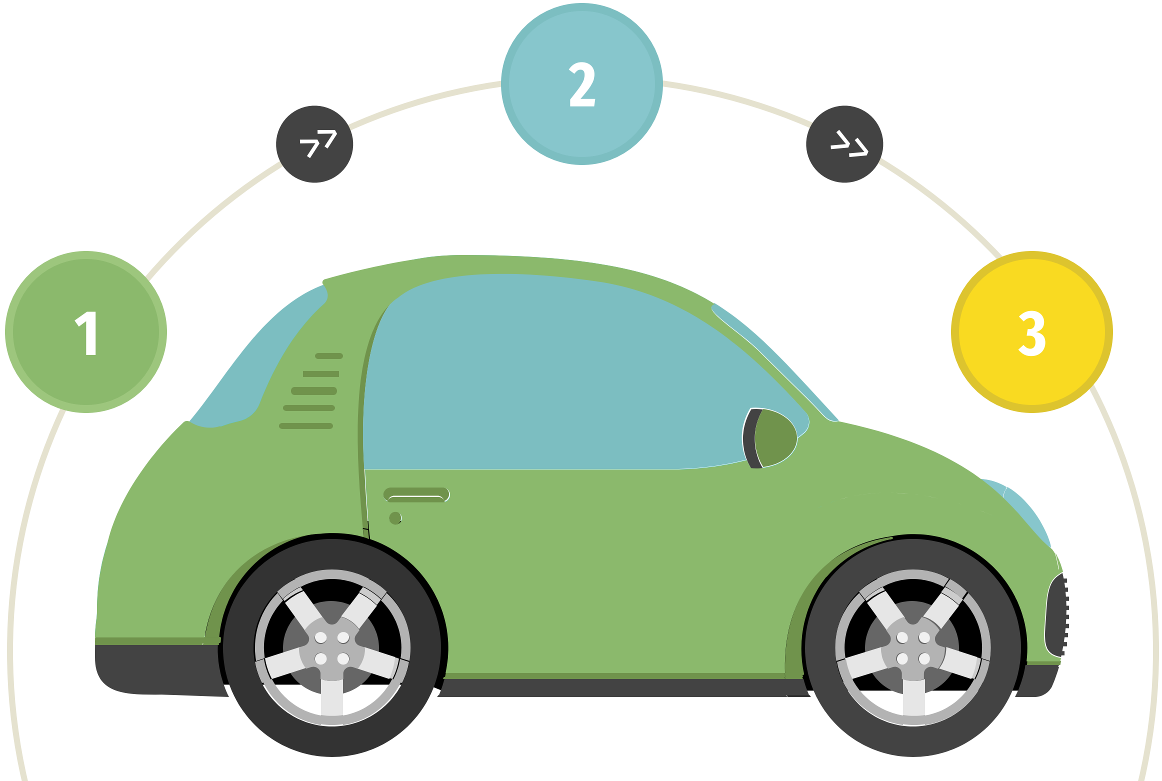
The Power Problem: Single Source Solutions Are Not Enough

Single-source Generation

Solar or wind alone provide inconsistent power availability depends on weather and time.

Fixed Installations

Most renewable systems require permanent or complex installation, slow setup, not ideal for emergencies.



Unsustainable

Temporary Fuel-Based Solutions like diesel generators require fuel logistics and emit CO_2 → not practical for disaster response.

Our Solution

Our Solution

Solar + Wind Hybrid

Capture energy day and night.

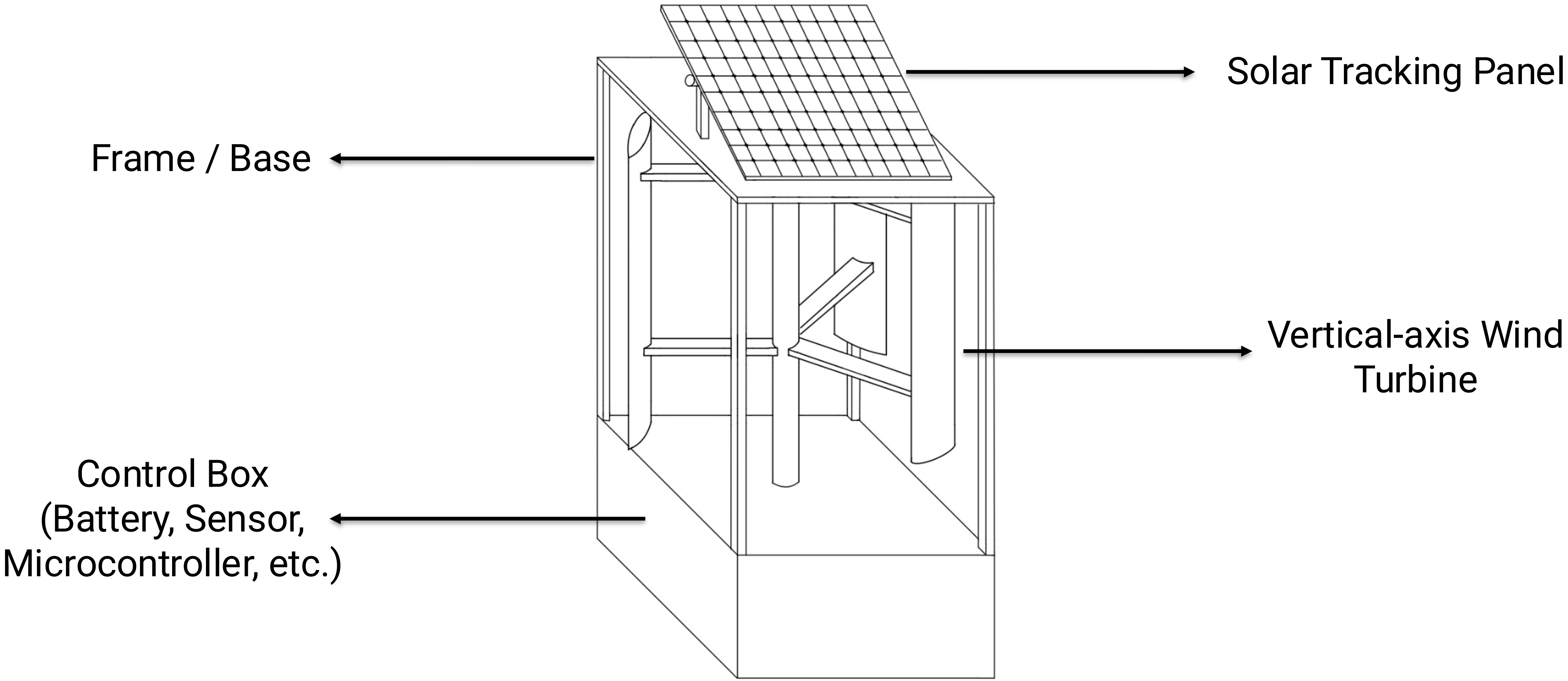
Portable & Modular

Easy and fast deployment.

Designed for Emergency

Emergency and off-grid operations.

Hybrid Vertical-axis Wind Turbine & Tracking Solar Panel



Prototype & Deployable Main Design Requirements

Hybrid Energy Capture	Portable and Compact	Stable and Durable	Safe Operation	Accurate Solar Tracking	Modular and Scalable	Rapid and Easy Assembly
Wind and solar, generate power in varied conditions.	Lightweight, foldable and easy to transport	Withstand harsh environments (wind, rain, dust) reliably.	Weatherproof and secure to prevent user and wildlife hazards.	Follows sun to maximise output.	Allow system expansion or upgrades based on user needs.	Quick setup without special tools

Existing Solutions

Vertical-axis Wind Turbine (VAWT)

1 **Omnidirectional**

Works in variable wind conditions.

2 **Simple**

Clean Mechanical design, low maintenance.

Fixed 1

Set installation, mainstream products not portable.

Poor Low Wind 2

Poor self-start at low wind speeds, limited output during light winds.

Solar Tracking System

1 Improve Efficiency

Single and dual-axis trackers improve solar efficiency (up to +30 & +40%).

2 Availability

Widely used in permanent solar farms.

Fragility 1

Heavy and complex, unsuitable for portable applications.

Dependent Systems 2

limited efficiency in off-grid scenarios, for solar dependent systems

Hybrid Commercial Units (Solar + Wind)

1

Reliable

Solar + wind combination, more effective than single-source.

1

Heavy & Complex

Heavy and permanent to setup, not portable or modular.

2

Practical

Useful for off-grid homes or cabins, not dependent on one power source

2

Limited

Limited scalability or field repairability, not suited for disaster response.

The Design Process

Overview of Design Process

1

Concept Development

Defined hybrid + portable system idea. Establish product specifications and sketches

2

CAD Modelling

Created virtual assembly and consider manufacturing methods (3D printing, aluminium profiles, purchased standard parts).

3

Evaluation

Assessed size, weight, and supplier availability, refined part choices to fit project budget and university supplier list.

3

Finalisation

Optimised for prototype build, standardised parts, and locked design for manufacturing and assembly.

What Worked Well in The Design Process

Clear hybrid + portable concept.

CAD Modelling with Manufacturing Focus

Standard parts reduced custom manufacturing.

Iterative Design Refinement

Simple and Effective Solar Tracking and VAWT Mechanism

What Could be Improved in The Design Process

Early size and weight estimation.

Solar and wind component layout.

Manufacturability in design phase.

Wind Turbine Blade Design

Standardisation Across Subsystems

Design Process > Prototype > Deployable

Assumptions

Prototype assembly would work as designed without needing complex rework.	
Parts ordered would be available and fit together without major adjustments.	
Materials and parts limited to university supplier and budget.	
Manual assembly acceptable for prototype stage. Free cut for turbine blades	
Simple single-axis solar tracking considered sufficient.	

Limitations

No integrated energy storage	
Simplified Solar Tracking Control System	
Assembly involved multiple manual steps	
Limited durability and outdoor real-world testing	
Wind turbine low wind performance	

Prototype Design and Innovations

Hybrid Generation System → Solar + Wind Combination

01

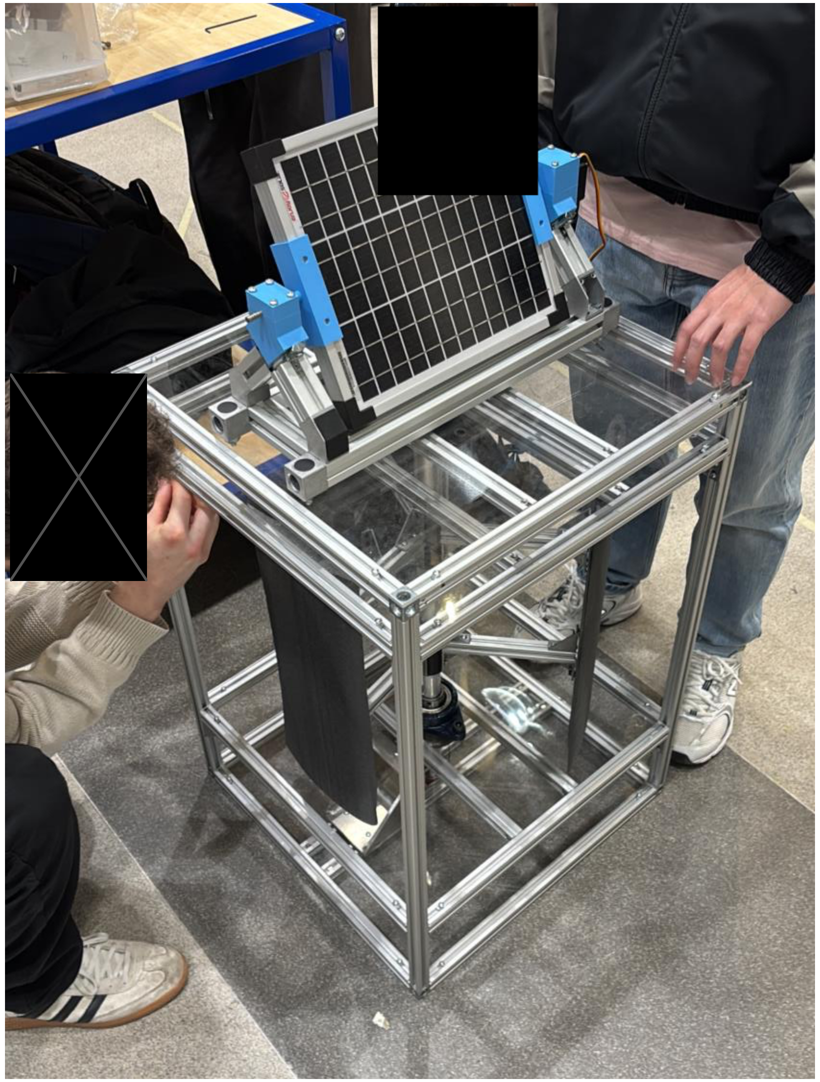
Allows continuous power output across day/night and weather variations.

02

Solar compensates when wind is low, wind compensates when solar is unavailable.

03

Directly addresses intermittency, improves reliability.



Single-Axis Solar Tracking

01

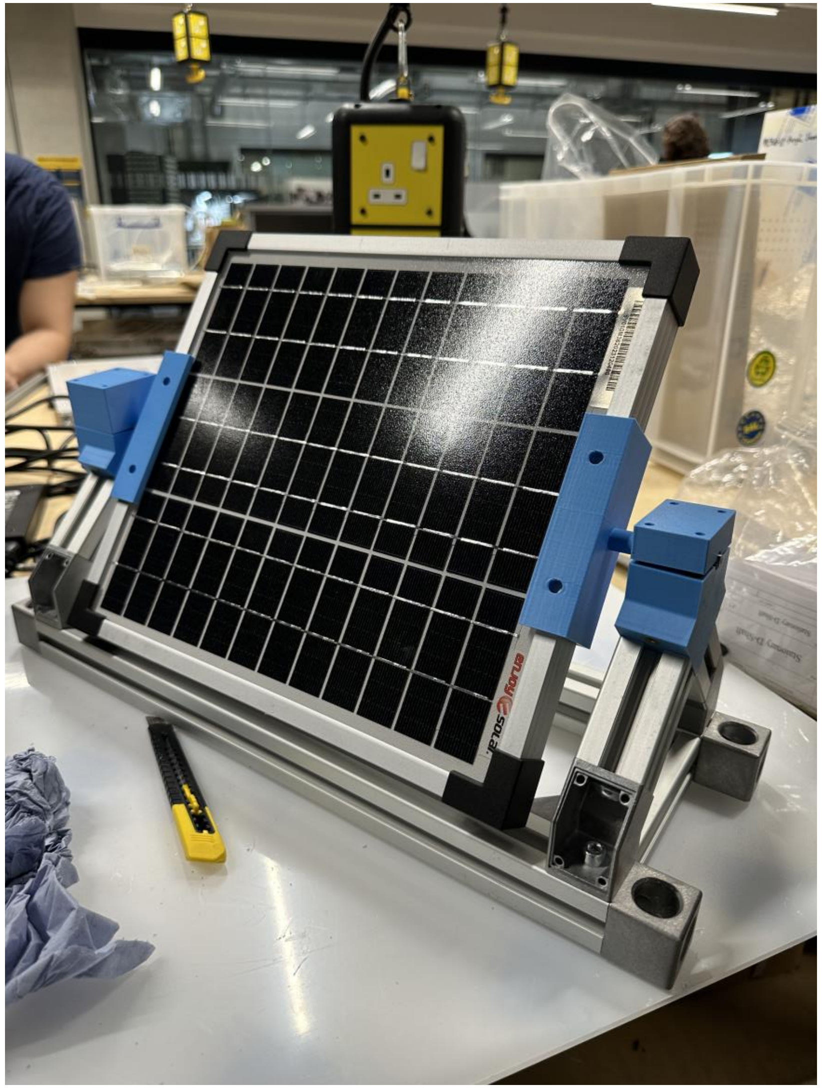
Simple mechanism, reduced cost and complexity vs dual-axis.

02

Increases solar capture up to ~30% vs fixed panel.

03

Balances performance and ease of implementation.

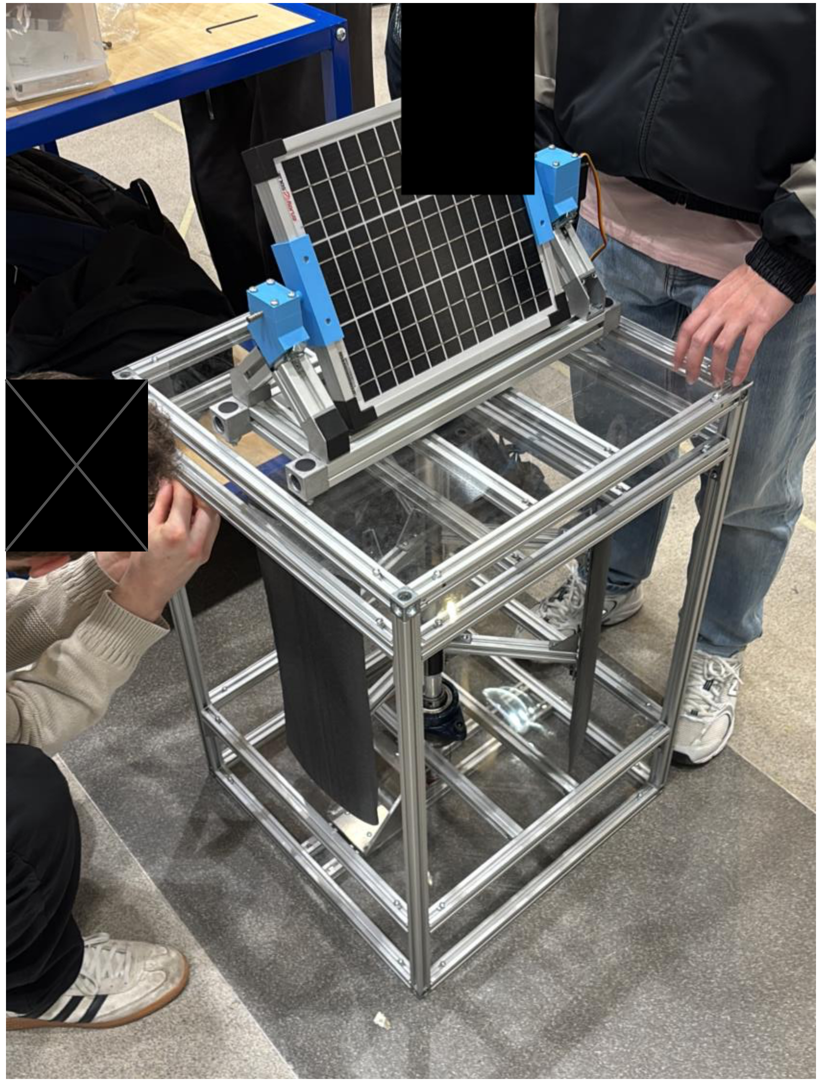


Compact Vertical Integration

01 Solar tracker mounted directly above VAWT, saves space.

02 Reduces footprint, critical for residential/portable use.

03 Avoids interference between wind and solar harvesting

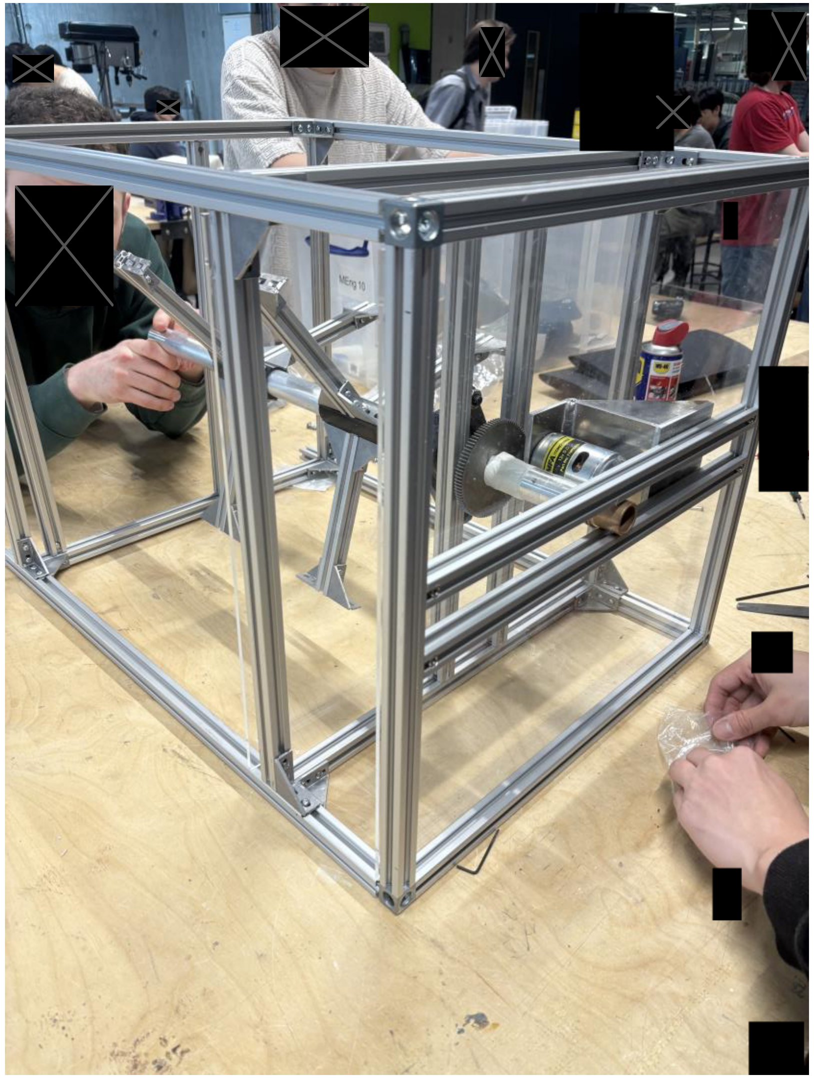


Low-Cost and Accessible Parts

01 Prioritised off-the-shelf and 3D printed parts.

02 Avoids expensive custom fabrication.

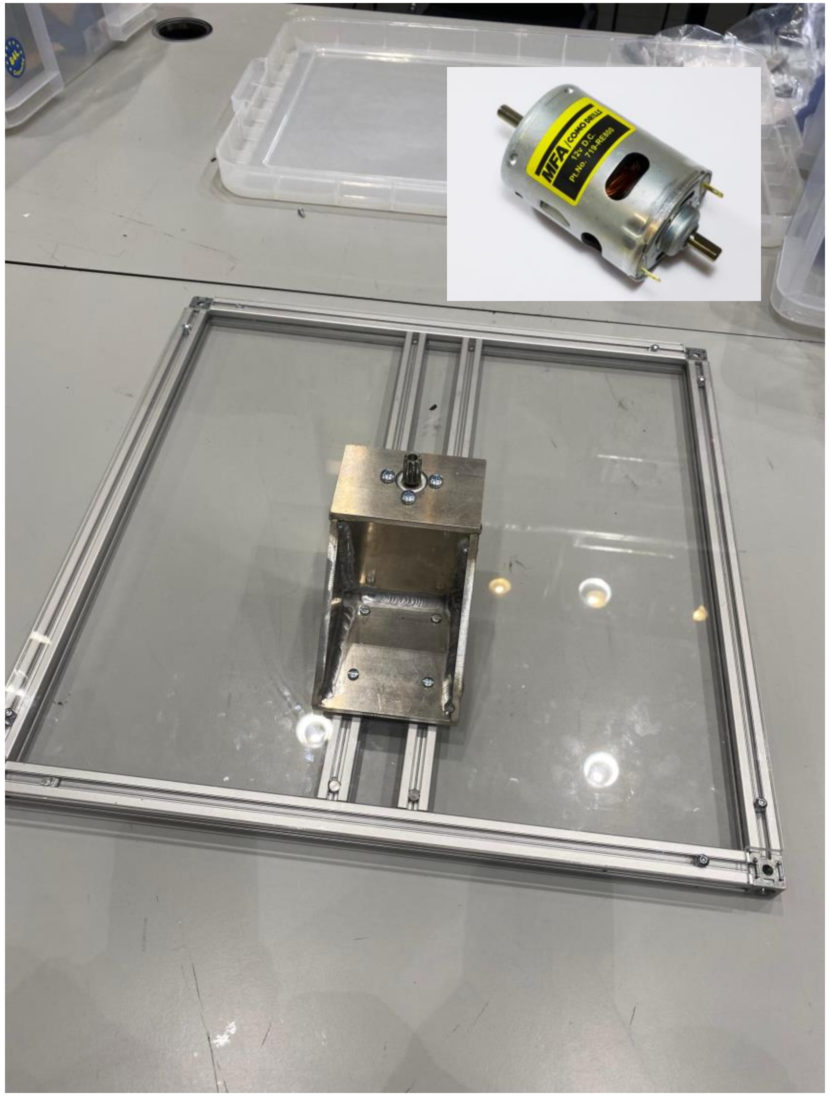
03 Simplifies maintenance and ensures user-serviceability.



Prototype Assembly

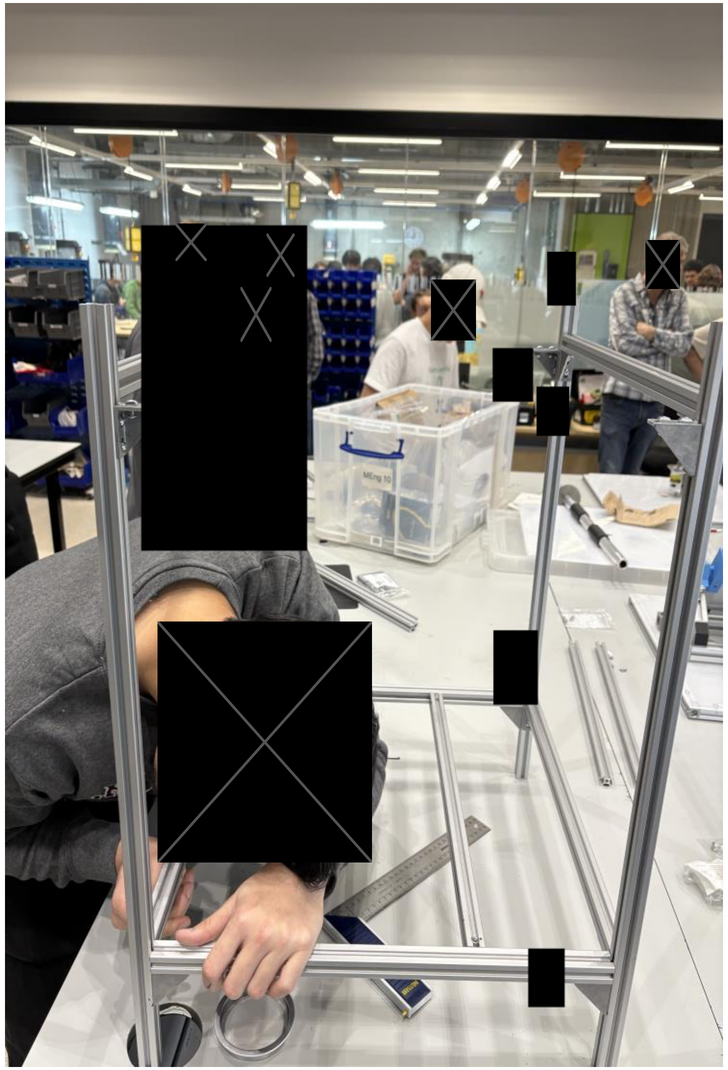
VAWT Assembly

VAWT Assembly

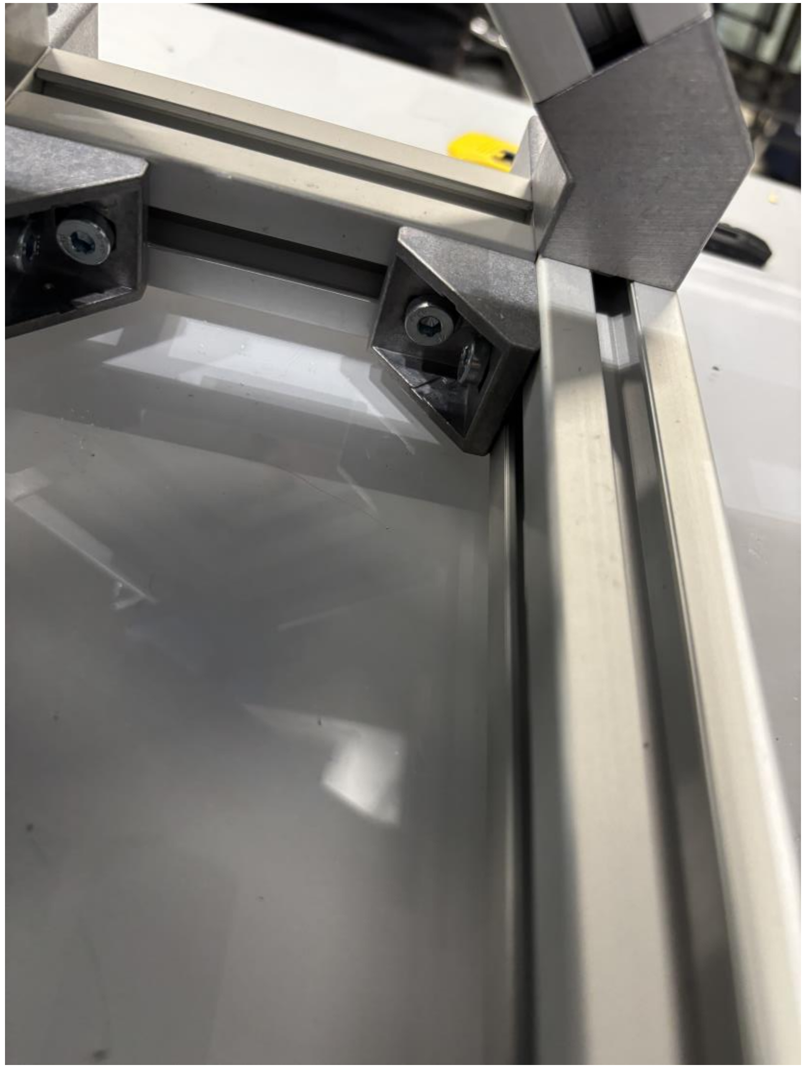


Cage Assembly

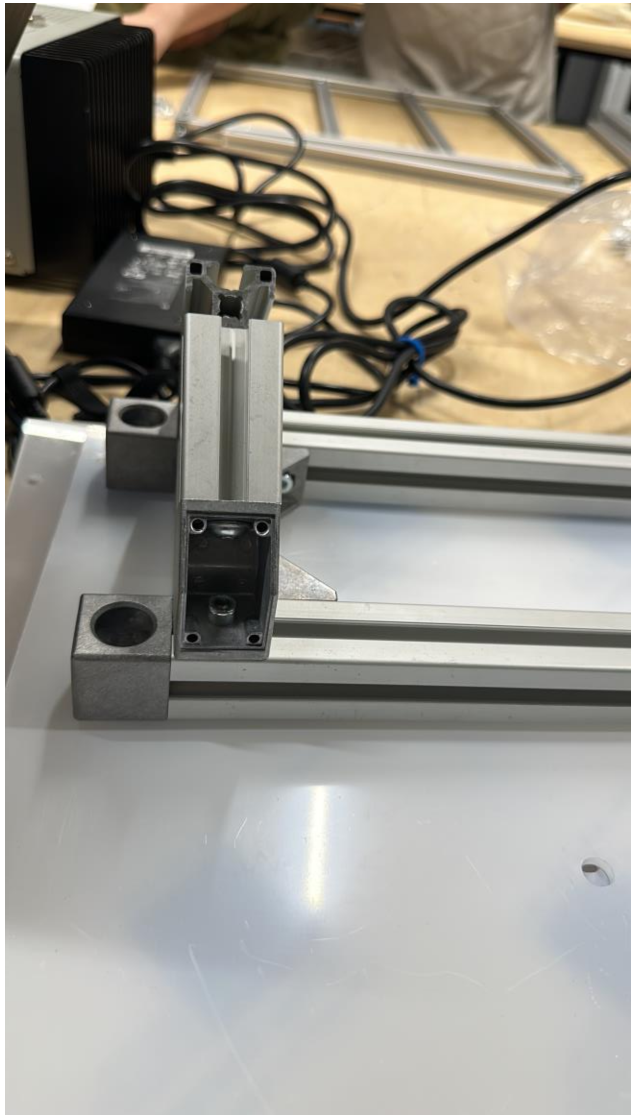
Cage Assembly

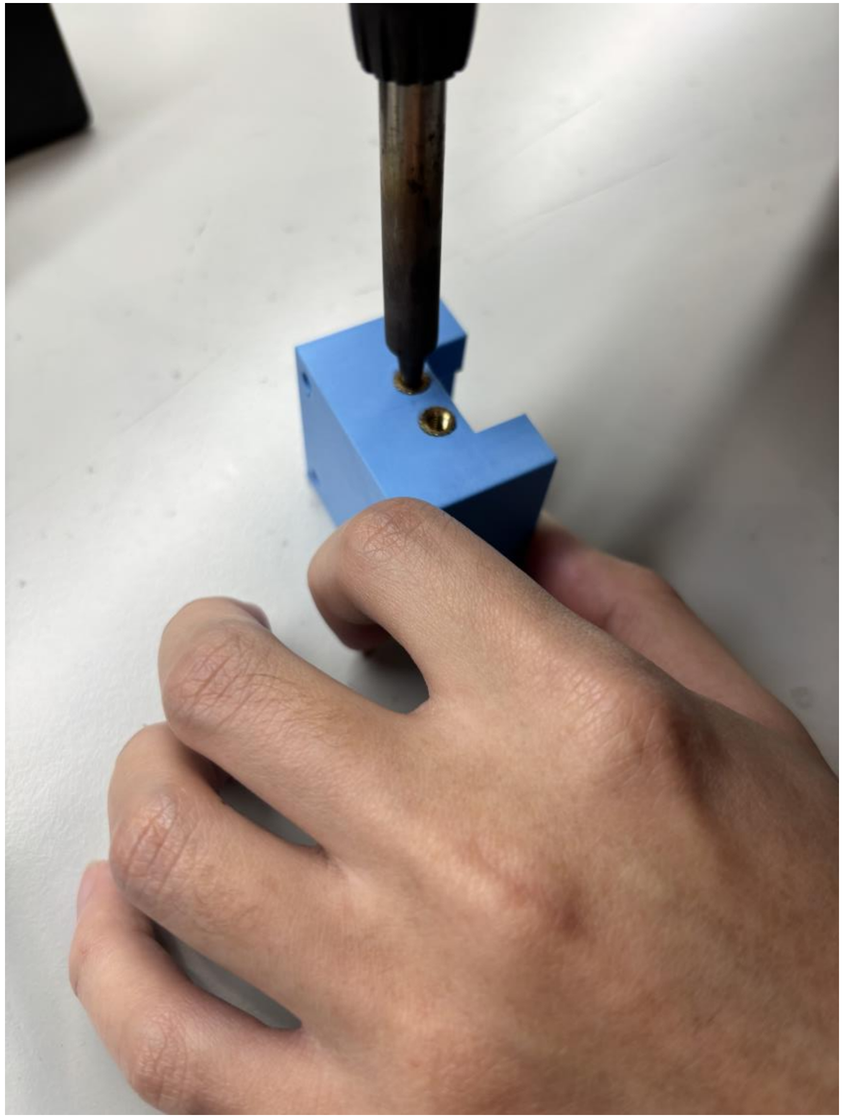


Solar Assembly

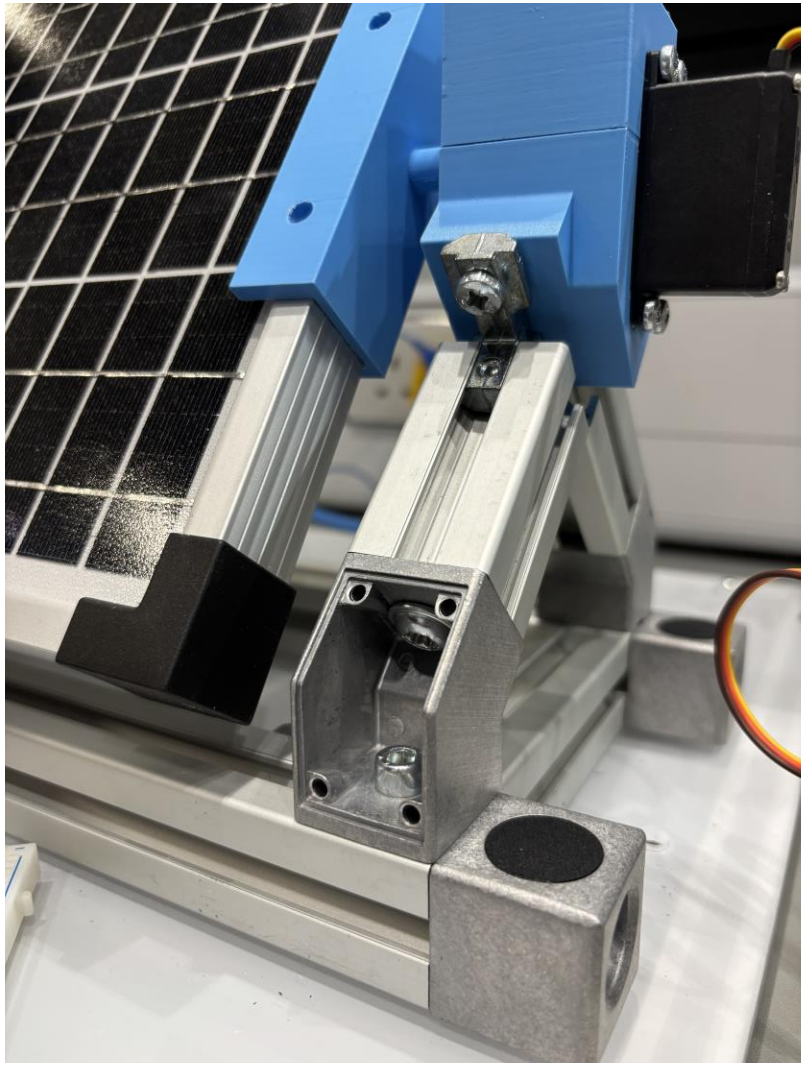


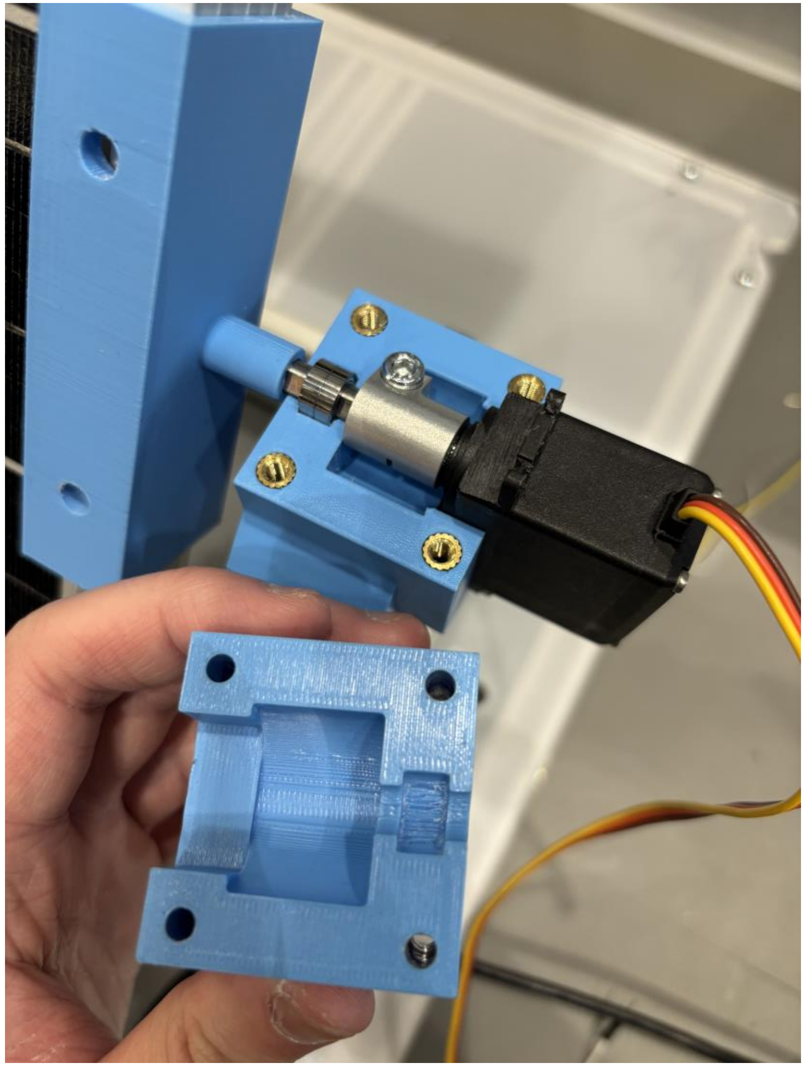
Solar Assembly



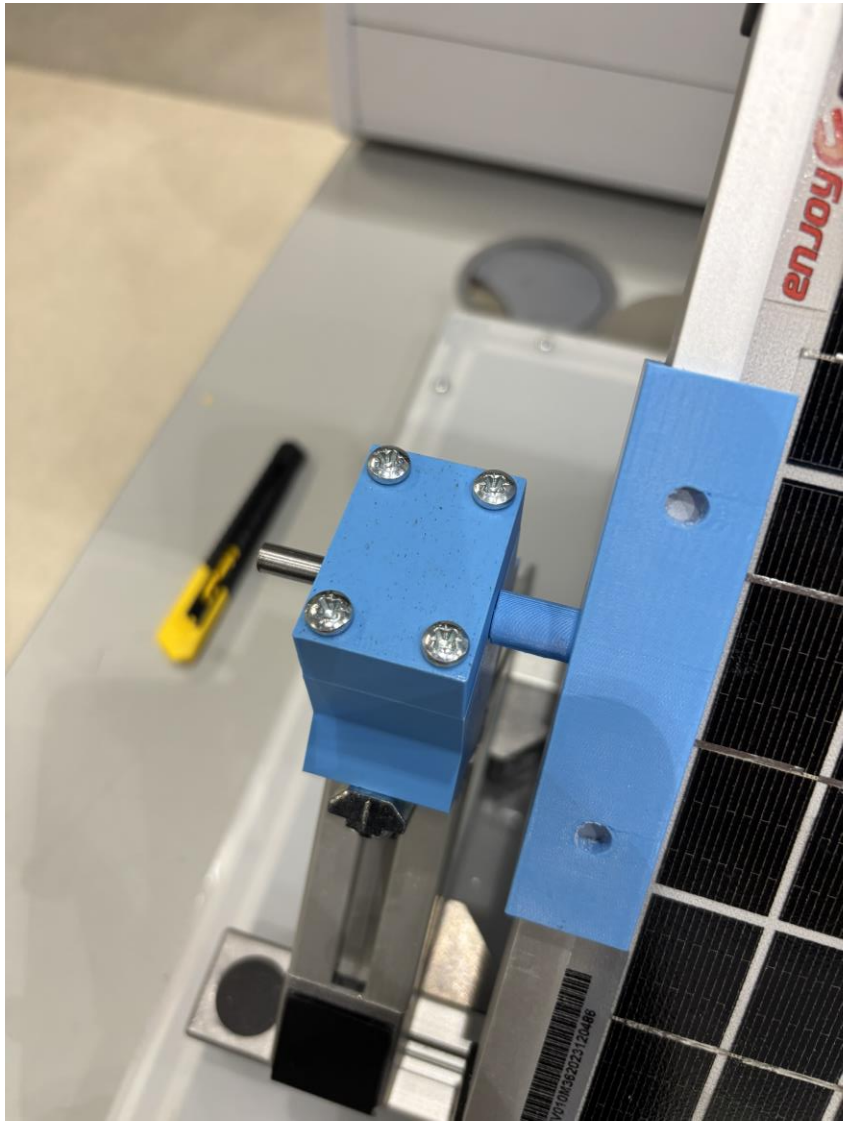


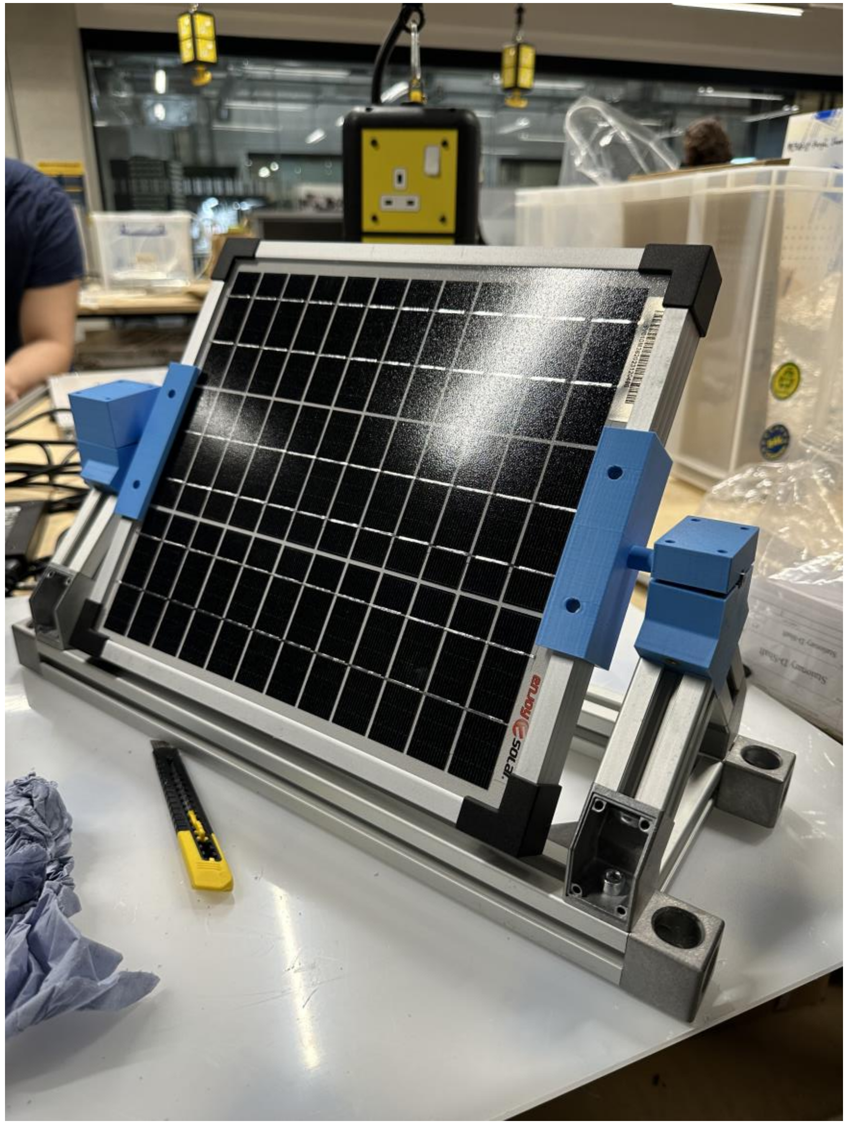
Solar Assembly





Solar Assembly





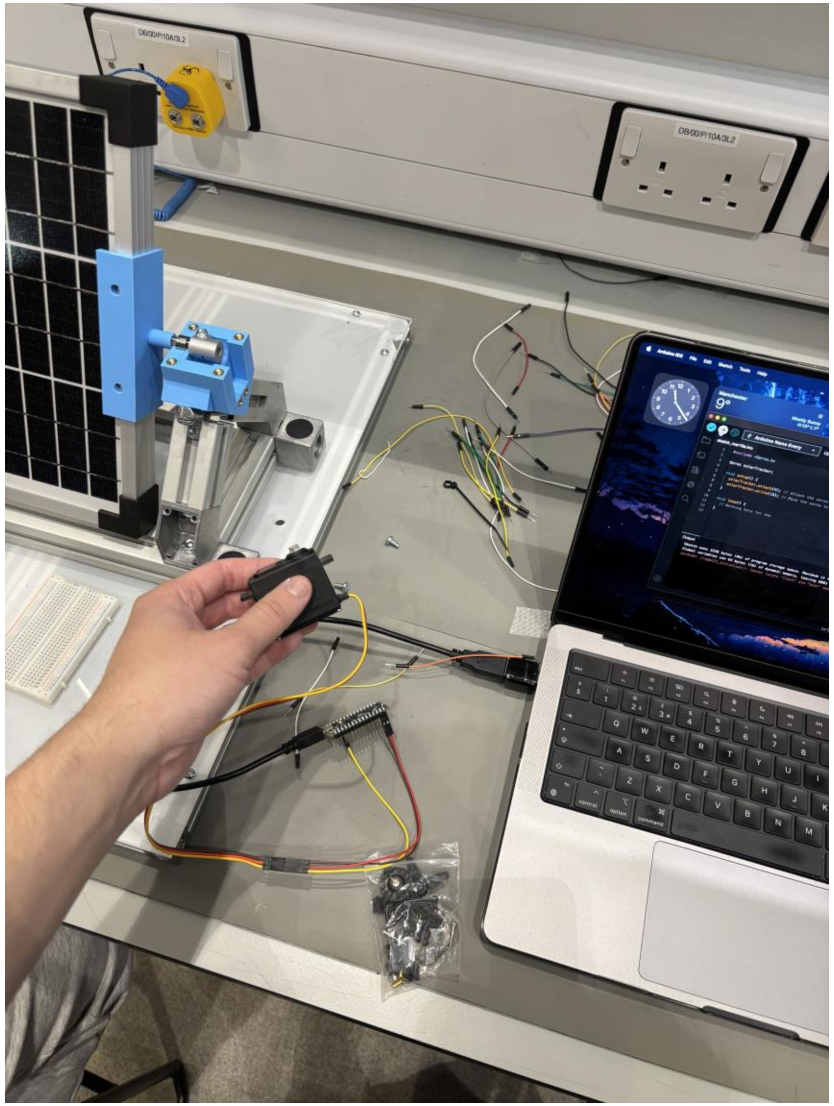
Prototype Testing

VAWT Testing

- Rotor assembly rotates about the vertical axis, transferring mechanical energy to a large gear mounted on the shaft.
- Large gear is engaged with a smaller pinion gear attached to the motor, forming a gear reduction system with a 9:1 ratio.
- As the rotor turns, the gear interaction increases the rotational speed at the motor shaft, enabling power generation.
- There were some defects in manufacturing of outsourced parts, so performance testing was done manually.
- Electrical output verified using a multimeter connected to motor terminals to provide evidence of power generation.

Solar Testing

- Single-axis tracker → simple design without sensors or automatic control.
- Moves from 0–180 degrees → designed to track sun position across ~8 hours.
- Testing used accelerated mode → full sweep in 1 minute to demonstrate range and functionality.
- Stepper motor and programmed sweep → operated smoothly and reliably.
- Simple, low-cost solution ideal for prototype stage → will consider automated tracking in deployable version.



Deployable Product

Deployable Product

Critical Improvements from Prototype - VAWT

01

Passive variable pitch system driven by cam and follower mechanism, derived from academic papers

02

Slotting and folding mechanisms for ease of assembly

03

Better power generation by utilising a brushless DC generator

Key Features – Cam and Follower Mechanism

01

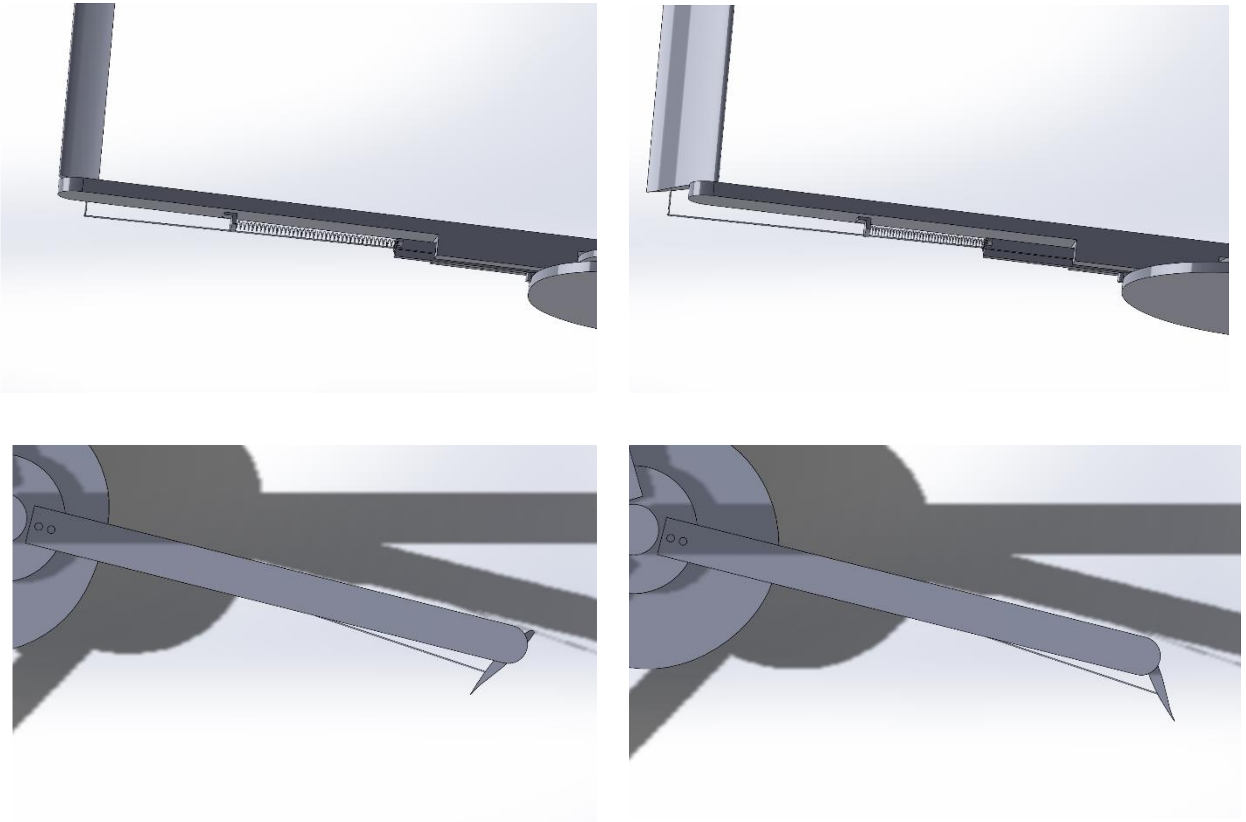
Passive operation, no external power required – blade pitch adjusts automatically using mechanical motion of rotor

02

Variable pitch control – cam changes pitch angle as it rotates

03

Mechanical simplicity and durability – simple mechanical components designed for robustness and low maintenance

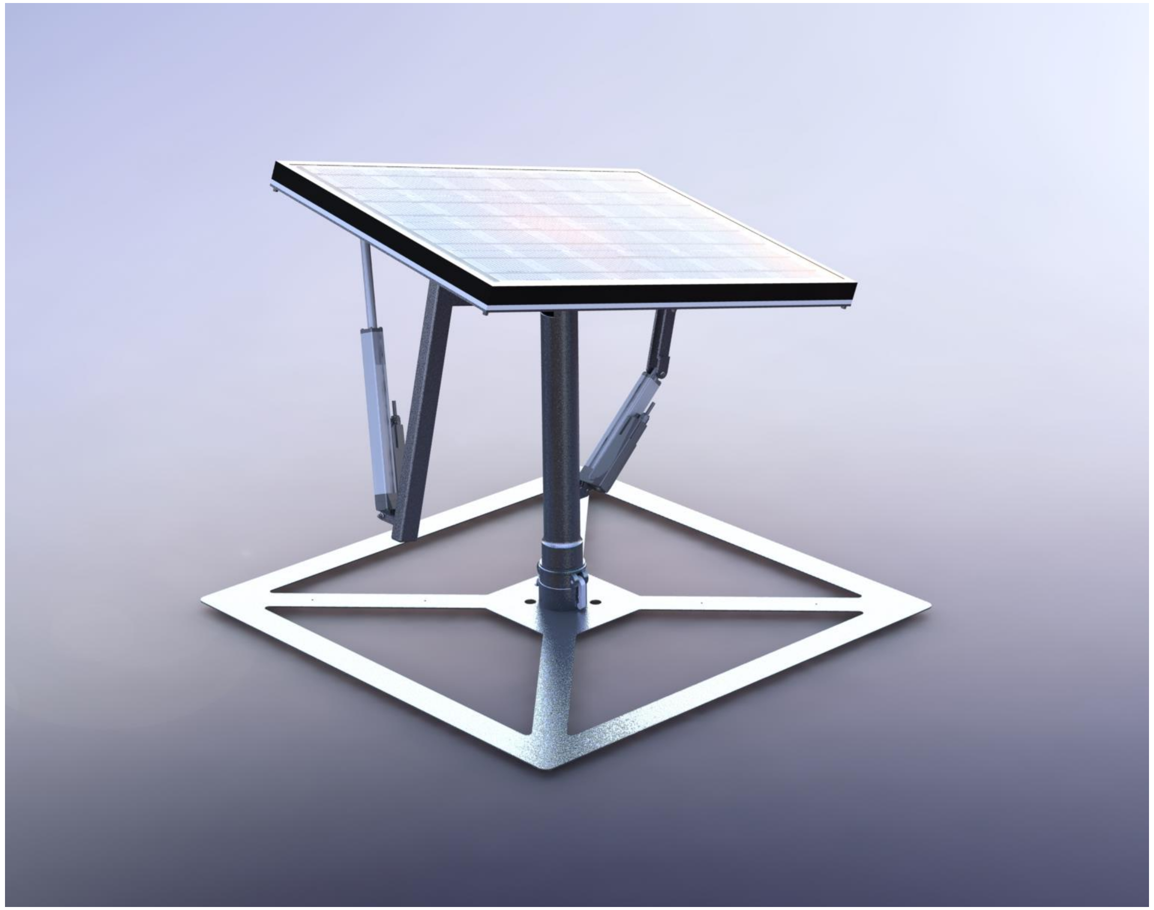


Critical Improvements from Prototype – Solar Tracking

01 Upgrade from Single-Axis to Dual-Axis Tracking

02 Integrate Sensor-Based Control System

03 Optimise Mounting and Structure for Stability and Weight



Key Features – Dual-axis Solar Tracking

01

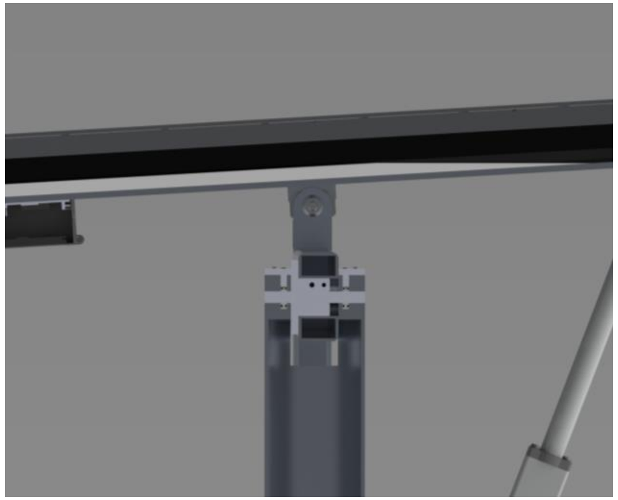
Dual-axis movement captures optimal sunlight angles for consistent and efficient energy generation.

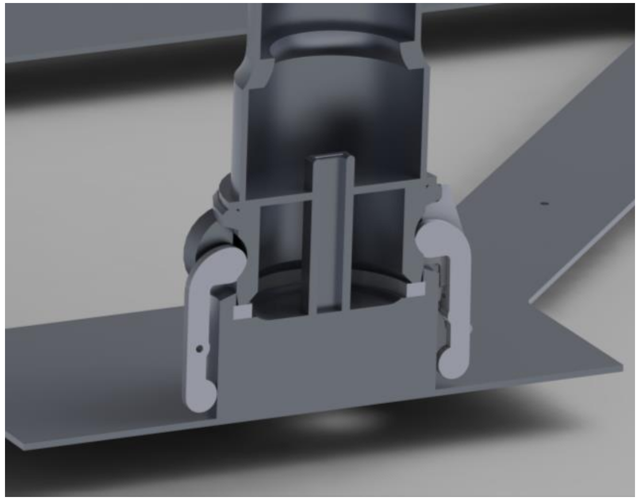
02

Sensor-based control provides fully autonomous sun-tracking without user input.

03

Integrated design mounts above VAWT without increasing footprint, maintaining portability.





Key Features – Dual-axis Control System

01

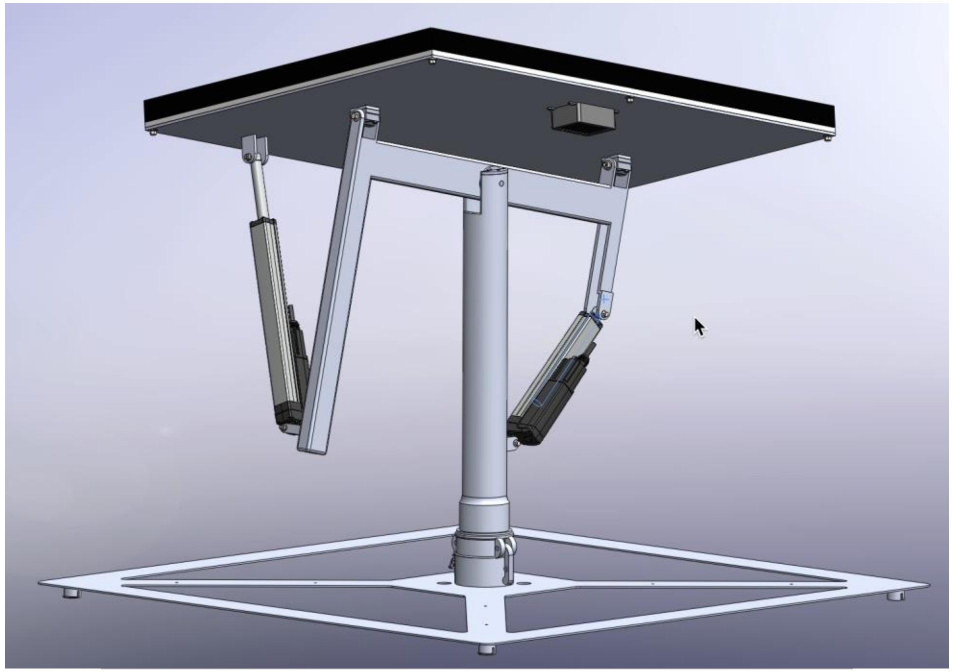
Uses GPS and time sensor

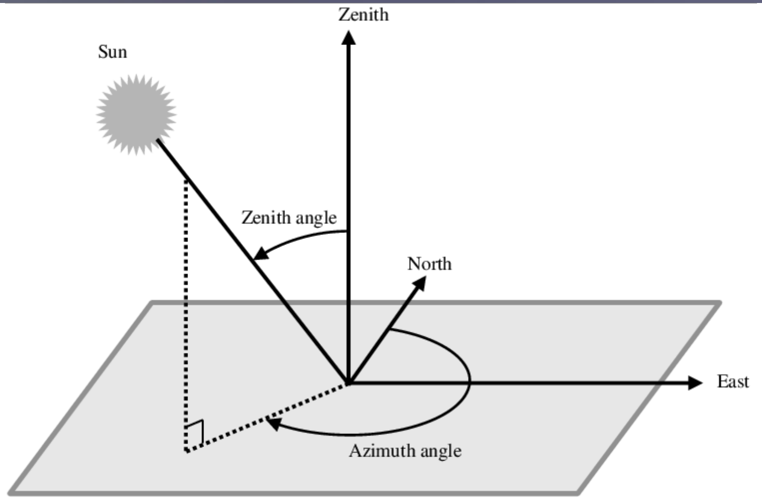
02

Calculates sun position using National Renewable Energy Laboratory (NREL) Solar Position Algorithm

03

Solar zenith and azimuth angles in the period from the year -2000 to 6000, based on the date, time, and location on Earth





Deployable Product

Product Assumptions

Maintenance will be infrequent and user-manageable.	📦
Users have basic skills for assembly and setup.	🛠️
Typical emergency power demands from users.	🏷️
Modular parts will be manufactured to precise tolerances.	🔧
Moderate wind and sunlight conditions during operation.	🌞

Known Limitations

Limited integration with grid and advanced battery systems.	⚡
Advanced solar tracking and pitch systems increase mechanical complexity and maintenance needs.	☀️
Assembly Still Requires User Effort and Tools	🔧
Durability under extreme outdoor conditions not fully validated.	🛡️
Compact design restricts maximum solar and wind collection area.	🌀

Further Development of Deployable Product

01

Smart Energy and Grid Integration

Add advanced battery management and grid-tie capabilities for seamless energy use.

02

Material and Durability Upgrades

Use enhanced materials and coatings for long-term outdoor reliability.

04

IoT and User Interface Integration

Incorporate IoT sensors and mobile interface, show energy data, location, sun/wind coverage in real-time.

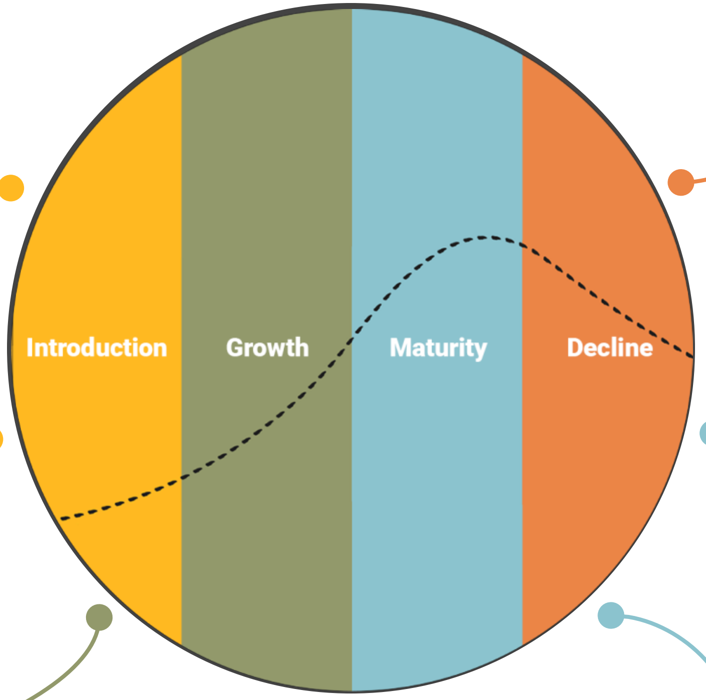
05

Extended Field Testing and Certification

Run long-term tests to validate reliability and achieve industry certifications.

Environmental and Societal Impact

PLC Environmental and Societal Impact



Off-the-shelf
Reduces manufacturing waste and enables easier end-of-life recycling

Simplified assembly
Reduces on-site construction impact and supports disaster/emergency use

Portable, modular design
Lowers transport and deployment emissions

Combined renewable energy system
Reduces reliance on fossil fuels

Planned durability and maintenance access
extends product life, reduces need for replacements

Safe design features
low-speed VAWT, secure fixings, reduces injury and wildlife risks.

Low-power electronics and tracking
Minimises energy consumption during use

Conclusion & Recommendations

Team Professional Practice Performance

1

Collaborative Working Environment

Rotating leadership ensured equal input, while adapted communication improved inclusion during design and review.

2

Improved Coordination and Project Planning

Switching to weekly meetings and a shared drive improved task clarity and accountability.

3

Constructive Feedback

Integrating BuddyCheck and GTA feedback enhanced deliverables, teamwork, and peer learning.

4

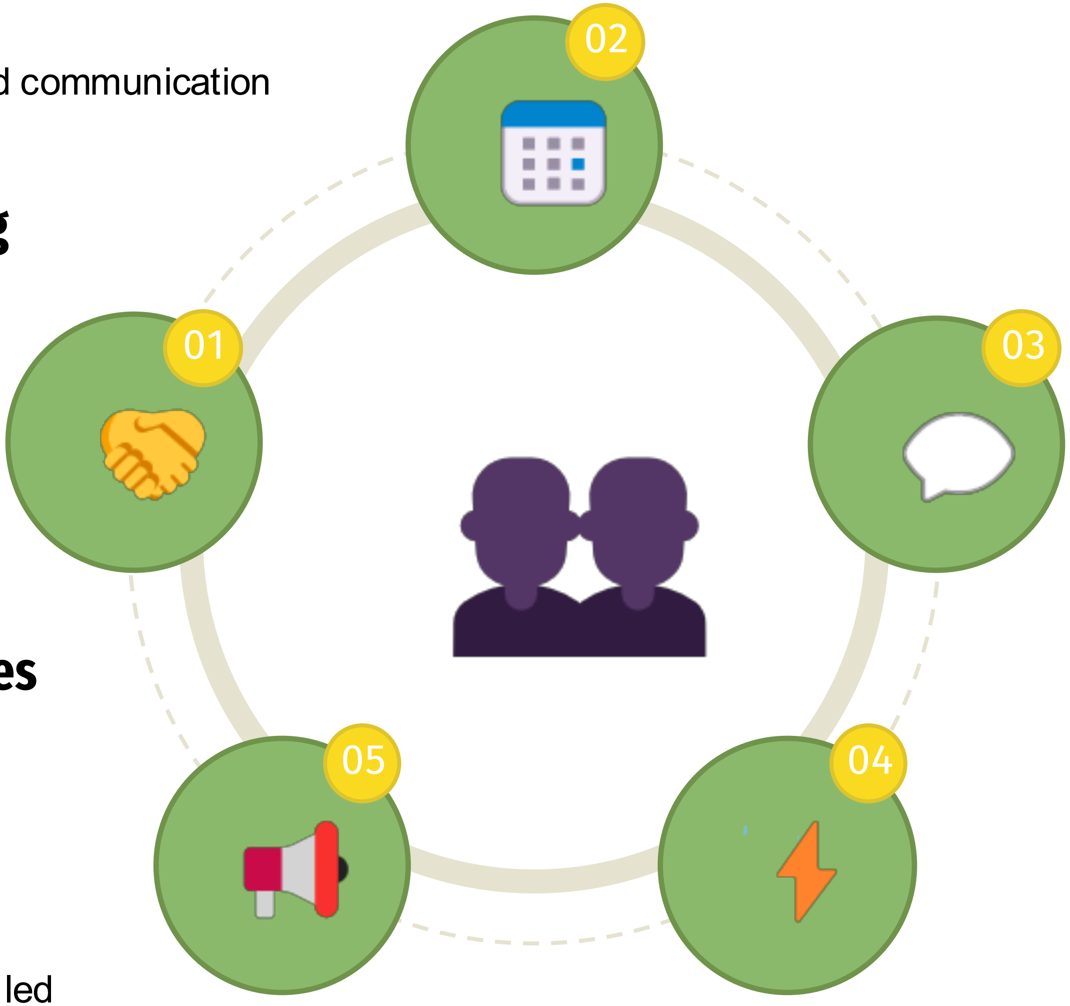
Adaptability & Resilience in Facing Challenges

Quick responses to setbacks kept the project on track without affecting deadlines or team morale.

5

Professional Documentation & External Communication

Formalised meeting minutes and clear communication led to more professional reports and presentations.



Summary of Main Achievements

1

Overcame Assembly Challenges

Adapted to poor-quality parts to complete and test the prototype.

2

Fostered Strong Team Identity

Managed language and cultural differences to build an inclusive, goal-driven team.

3

Coordinated Multiple Simulation Processes

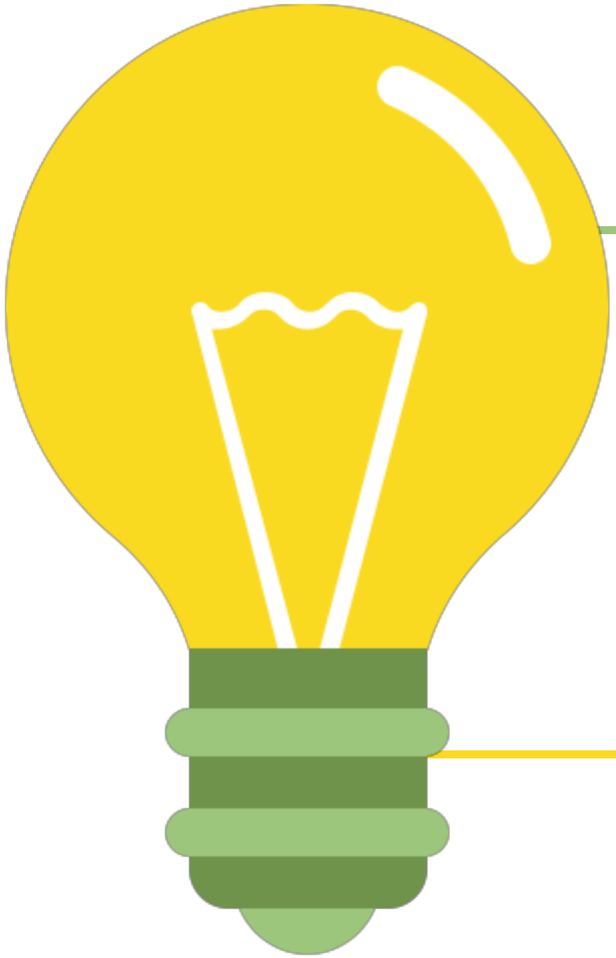
Coordinated multiple simulations to meet deadlines and deliver consistent design data.

4

Defined Clear Path to Deployable Product

Applied prototype insights to suggest practical improvements for a deployable, market-ready version.

Summary of Main Innovations



Hybrid Wind + Solar Energy Generation at Portable Scale

- Combines wind and solar in one compact system for reliable off-grid power
- Portable and quick to deploy — uncommon at this scale
- Generates energy day and night, in all weather conditions

Dual-Axis Solar Tracking Integrated on VAWT

- Most wind turbine solar setups are fixed, limiting efficiency
- Dual-axis tracking boosts solar capture on a mobile platform
- Mounted above the VAWT for a compact, hybrid energy system

Main Lessons to be Learned

Unreliable Supplier Information

Prototyping showed the need to verify supplier data to avoid fit issues and delays.

Internal Team Feedback = External Feedback

Peer feedback helped catch issues and improve the design before deadlines.

The Importance of Communication With Technical Staff

Early talks with university technicians help prevent manufacturing and assembling issues.

Design-for-Assembly Should Start Early

Late-stage issues could’ve been avoided by addressing assembly earlier in the design phase.

Recommendations for Improved Practice

1 Establish Robust Supply Chain Verification

2 Implement Design for Manufacture and Assemble from the Outset

3 Adopt Iterative Testing and Rapid Prototyping Cycles

4 Formalise Communciation Channels with Technical and Academic Staff