BIOSPHERE
SOLAR

Smart PV Box

Emir Dag

20-03-2025

Project Name
Smart PV Box

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Preface:

In front of you is my graduation report, written for my study Industrial Product Design at Rotterdam University of Applied Sciences. This report is the result of my graduation internship at Biosphere Solar, where I worked on the development of a Smart PV Box. During this internship, I not only gained a lot of technical knowledge about designing with PV solar panels, but I also learned what it is like to work together with a software engineer remotely. This brought a unique challenge but gave me valuable insights into international teamwork and product development. I also experienced what it is like to work in a small, close team where independence and working together go hand in hand. I really liked the open and friendly atmosphere in the company, where every morning starts with asking how everyone is doing. I would like to thank Siemen Brinksma and Abdul Ajeez for their guidance in the company and their valuable input during my project. I also want to thank Jelle Zijlstra for his role as school coach and for the coaching sessions that helped me shape my research and report. This internship was an educational and inspiring experience that helped me grow both professionally and personally. I look forward to using the knowledge and skills I gained in the future.

Emir Dag
20-03-2025, Rotterdam

Figure 1

Biosphere Solar, location Maasboulevard 100

Source: Biosphere Solar (2025)

Figure 2

Biosphere Solar, location Maasboulevard 100

Source: Biosphere Solar (2025)

Figure 3

Biosphere Solar, location Maasboulevard 100

Source: Biosphere Solar (2025)

Company introduction:

Biosphere Solar is an innovative company in the sustainable energy sector, specialized in developing and producing circular and modular solar panel systems. The company aims to support the energy transition by designing reusable and recyclable solar panels, helping to reduce waste in the industry.

Within Biosphere Solar, different departments work closely together to drive sustainable and technological progress. The R&D department focuses on innovation and product development, while the production team ensures efficient assembly of the panels. The company has an open and collaborative work culture, with short communication lines that support a dynamic and efficient way of working.

Biosphere Solar’s vision is to build a fully circular solar panel industry, where products are reused and repaired instead of thrown away. With this strategy, the company remains a leader in sustainable solar energy and responds to the growing demand for environmentally friendly energy solutions.

Project Background:

In the Global South, there is a growing need to support people in using solar energy more consciously. Current solutions often focus on apps and digital tools, which are not always accessible or engaging in these regions. There is a strong demand for low-tech, visual, and easy-to-use tools that match the daily lives and habits of users.
To meet this challenge, the design goal is defined as follows: create an interactive and visual interface for communities using Biosphere Solar panels in the Global South. The interface helps users stay aware of their energy use and encourages long-term sustainable behaviour. This project supports Biosphere Solar’s mission to make the solar industry more circular and to involve people actively in their own energy transition.

Before the start of this project, the following design question was defined:

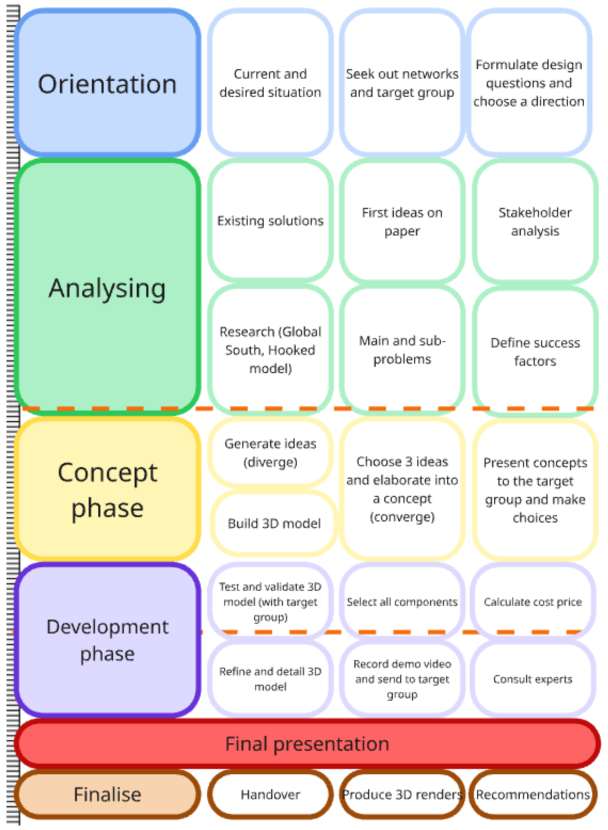
Design a visual and interactive product for users in the Global South, within a home, work, or educational setting, that helps them stay aware and engaged with their solar energy use, so that the product:

- A- *Supports* users in building **a weekly routine** around energy awareness through a product use.
- B-*Stimulates* users at the right moment to act **energy-efficiently** and offers ways to **share or compare** behaviour with others.
- C- *Is easy to use*, with at least **three core functions** accessible **without instructions**, for all ages and digital skill levels.
- D- *Includes elements* that match the local **energy context**, like energy sources, language, or habits.
- E- *Uses a modular structure* that can be **easily adjusted** or **expanded** for **different audiences or platforms**, without rebuilding the core system.

The project begins with the **orientation phase**, where the current and desired situation is mapped, networks are built, and design question is defined. This followed by the **analysis phase**, where research is done and key information is collected. After that comes the **concept phase**, where sketches are made and three concept are developed. One concept is selected as the most promising. This leads to the **development phase**, in which the chosen concept is tested with the target group. Based on their feedback, the process moves into the **finalisation phase**, where the final product is created. The full structure is shown in Figure 4

Figure 4

Projectstructure



Analysis

The project starts with research on people living in the Global South. This research reveals how they interact with products and the environments where the product will be used. To encourage habit formation, the book Hooked by Nir Eyal is studied and used as reference. A network of people from the Global South helps validate information and supports idea generation and product testing. This phase results in a clear list of requirements and design principles. To help with the idea generation four personas were created from the research on the global south.

Idea generation

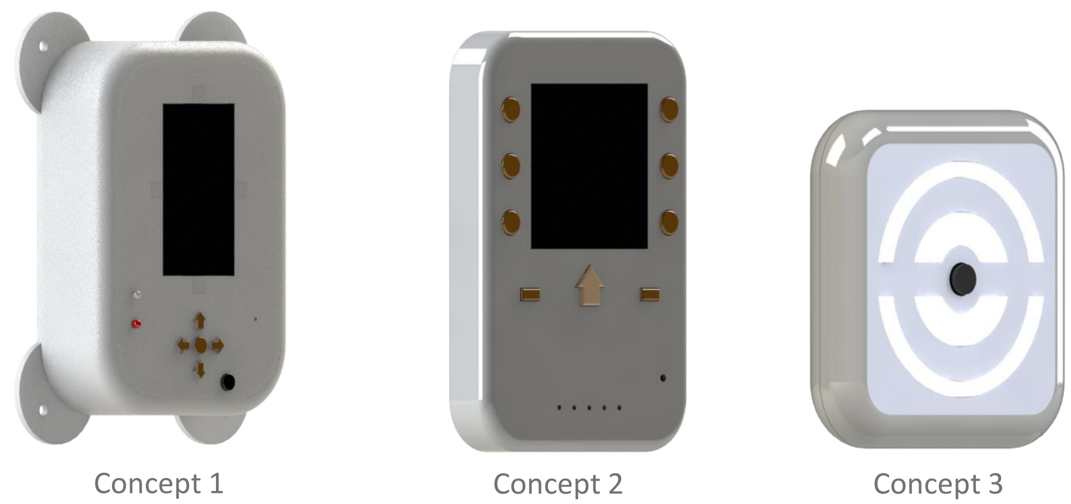
Based on the research conclusion and the four personas, several ideas are sketched and explained. These ideas are shared with the network from the Global South for feedback. Using the requirements from the research and the conversations with the network, three concept directions are defined: a wall-mounted display unit, a portable display unit and a display-free awareness module. For each direction, one matching idea is selected that is usable by at least two out of the four personas and that meets at least three out of the five success factors.

Figure 5

Photo of the prototype

Figure 6

3D model of concept 1,2 and 3



Concept Development

Each concept is developed on three key aspects: the aesthetic aspect, the functional aspect and the manufacturing aspect. In addition, a future vision is included. This vision covers the product vision, the circular plan and the end-of-life strategy. Each concept has a 3D model and is physically 3D printed at StadsLab Rotterdam (figure 6). A user can use the 3D model to see how the concept looks from the outside and how it is built.

Every concept includes a production plan with three stages:

- A pilot series of 50 units
- A small series of 1000 units
- A large-scale production of 5000+ units

Every concept has a Bill Of Materials with the estimated price for each product in the pilot series.

The display-free awareness module is chosen as the final concept. It is the easiest to produce, install, use and maintain, and has the lowest production cost of all three concepts. The concept is tested with the target audience to check the aesthetics and functionality. The test results are used to develop into a working product.

Product Development

All test results and feedback from the display-free awareness module are used to create a new list of requirements. A technical informatics expert helps define all components and checks the dimensions of the 3D model. The updated 3D model is made in OnShape and shows what the product looks like after production. A material research is done to choose the material that fits best with the requirements of the product. This model is made into a prototype by hand to test producibility. It is designed for pilot series but is future-proof and ready for small-scale production.

Conclusion

The final concept answers the main design question by helping users in the Global South become more aware and involved with their solar energy use. It is easy to use, low-cost, and fits different environments. The result is shown in Figure 5. The next pages give insight into the problem exploration, research, and steps taken to reach the destination.

Exploration of the Design Question

Problem Definition

This project develops a SmartPVBox that keeps users in the Global South continuously aware of their solar-energy use at home, work, or school.

Current situation:

- Biosphere Solar produces open-source circular PV panels.
- Off-grid users lack dependable electricity; on-grid users face frequent outages (IEA, 2022).
- Older users often have limited digital literacy (Pew Research Center, 2019).
- Existing dashboards rarely maintain long-term engagement.

Desired situation:

- Provide a solution that continuously shows energy production and use.
- Use visual cues, sound, or gentle vibration.
- Create weekly behaviour routines (habit loops)
- Empower users with local, modular, low-cost hardware.

Key Challenges

- Recruiting test users from four pilot countries
- Balancing low-tech reliability with modern UX
- Prototyping locally with CNC instead on injection moulding.

Client:

HUMAN -> Daughter company of Biosphere Solar

Other Stakeholders:

- Test users from the Global South
- Vendors and Suppliers
- Government bodies and regulators
- Grid operators
- Smart PV Developers
- Open-source developers

Users:

Individuals and communities across Sub-Saharan Africa, South Asia and Latin America; both on-grid and off-grid contexts (Global South Politics, 2018)

Main Design Question

How can a visual and interactive product help users in the Global South stay aware and engaged with their solar energy use at home, work or in education?

A. Weekly Energy Routine
How can the product help users build a weekly routine?

B. Energy-efficient behaviour
How can the product nudge action at the right moment?

C. Easy & Accessible
How can core functions remain fully useable without manuals or prior tech knowledge?

D. Local Fit
How can the interface adapt to local language, energy sources and cultural norms?

E. Modular Upgrade Path
How can the design stay modular, so new features or audiences can be added quickly?

Research overview: User Needs, Context, and Market Analysis in the Global South.

Research Question

To design a useful and engaging energy-awareness product for the Global South, research focused on the following questions:
- Which countries in the Global South are most ready for solar adoption?
- How do users in these regions interact with product?
- What product aesthetics fit the local context?
- What energy-related products already exist?
- How can long-term habit formation around product use be supported?

The term ''Global South'' is used in this project to refer to regions with shared sociopolitical and economic characteristics, rather than purely geographic location. This includes areas in Africa, Asia, and Latin America. (figure 7)(Clarke, 2018)

Summary Of Findings (See appendix 1.1- Global South Research)

Country and Context analysis
- Nigeria, India, Brazil and South Africa show active solar use and provide diverse user contexts.
- These countries represent urban, rural, tech-savvy, and low-tech environments.
- Four personas were created based on this analysis (see Appendix 1.2- Persona Cards)

User Behaviour and Environment
- In rural and low-income regions, many users lack experience with digital technology and interfaces, especially elderly users (Pew Research Center, 2019). This limits interaction with standard app-based platforms and requires visual and intuitive UI design.
- Use of icons, visual cues, and multilingual support is key.
- Devices must be tamper-proof, lockable, or theft-deterrent, especially in African regions.
- Product must be affordable due to wide income gaps.
- User base is diverse: both low-tech and high-tech users.

Product aesthetics
- Design should feel ''futuristic but friendly'': smooth shapes, few buttons, clear screen.
- Suggested materials: something sustainable and low cost
- Colours: Earthy and warm tones that blend into homes and schools.
- Structure: Modular- Battery and display should be replaceable or detachable

Existing Products
- Many users already own phones and laptops.
- Successful products are respectful in tone- not childish or playful.
- The product must treat the user as capable and serious.

Habit formation research
Behavioural strategies such as triggers, feedback loops, and internal motivations play a crucial role in long-term habit formation. According to Eyal(2014), successful products create habits by guiding users through a consistent cycle of triggers, actions, rewards and investment. (see Appendix 2- Hooked Model Analysis)

Key Insights

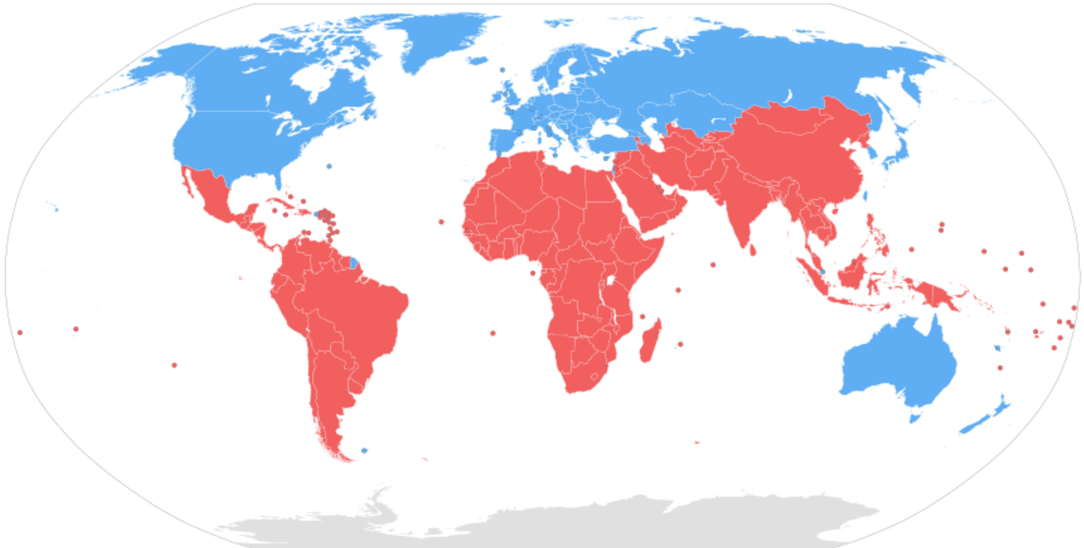
- **Target countries**: Nigeria, India, Brazil, South Africa– selected for reach and diversity.
- **Design simplicity is essential**: Interfaces must be intuitive across age and skill levels.
- **Security is Critical**: Device must resist theft and look uninviting to steal.
- **Style matters**: Neutral, smart design works better than playful styles.
- **Habits need Cues**: Subtle visual/sound signals encourage long-term use.

Conclusions and Design Requirements

The research leads to the following design requirements:
Multilingual, Visual UI without text-heavy instructions.
Tamper-resistant and lockable housing.
Modular setup: swappable battery, detachable screen.
Affordable components: locally sourced where possible.
Earth-tone aesthetics using low-cost, sustainable materials.
Respectful tone, suitable for adults and youth
Gentle light/sound feedback to support habit building

Figure 7

Countries classified as part of the Global South (in red).



Source: Clarke, 2018

Research overview: Design Validation and Prototyping Research

Concept Development & User Testing

Three product concepts were developed based on earlier user and context research (see page 5). Each concept emphasized usability, visual clarity, and local feasibility. The concepts were presented to five participants from the target group (Figure 8) and the technical team.

Results: Most of the test users and team members selected Concept 3 as the most intuitive and user-friendly option (Figure 9). This concept became the basis for further development.

Appendix 6.5 – Design Validation & Conclusion
(Appendix 6.1-6.5 for concept sketches, test feedback & voting results)

Figure 8
Test user with the 3 concepts

Figure 9
Test user approving concept 3

Iterative Prototyping & Technical Testing

To validate form, fit, and manufacturability, the chosen concept was iteratively prototyped using CNC milling. A total of 5-7 iterations were made to improve:

- Assembly alignment
- Internal component fit (Sensor's power supply, internal cabling, connectors, microcontroller and other)
- Material tolerance

The final prototype ensures clean assembly without special tools and integrates electronic components securely.

This hands-on testing phase was essential to refine the design for real-world production

Appendix 8.1 - CNC Prototyping Process
(Photos, Measurements, Notes on Improvements)

Material Research & Production Feasibility

Several materials were assessed for cost, sustainability, availability, and CNC compatibility. The Final choice was Spruce wood, due to its affordability and local availability in regions of the Global South.

- Easy to machine with standard CNC tools
- Locally sourced in many pilot regions
- Less suitable outdoors (product intended for indoor environments)

Given the low quantity for a pilot series, injection moulding was rejected. CNC machining was chosen to support local employment and avoid upfront tooling costs.

Appendix 3 - Material Selection Table & Production Feasibility

Color Testing Based on Personas

Three color variants of the final housing design were tested using mood boards. Participants linked to the personas evaluated them based on emotional resonance and context relevance (home, school, business).

Results: The warm earth-tone version was most preferred, due to familiarity, calmness, and low-tech appearance.

Quotes from persona-based testers:

- ‘’It feels like something I already own’’
- ‘’It looks like it would fit in my home’’

Appendix 4 - Colour Testing & Persona Feedback

Conclusion of Design Research Phase

This Phase ensured that the selected design is:

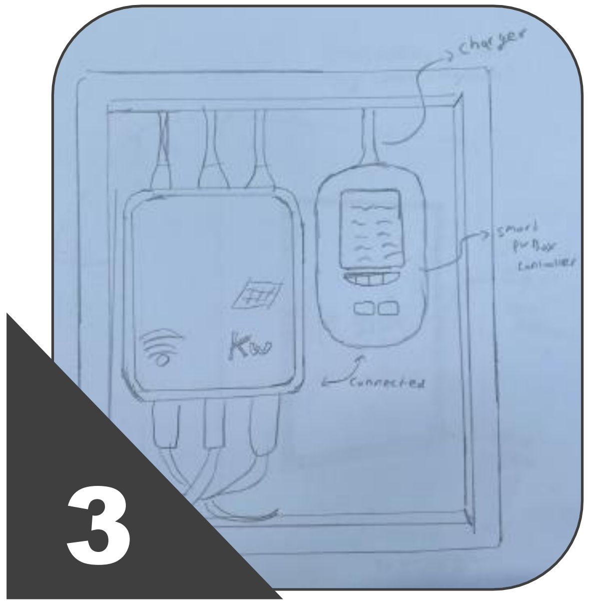
- Aligned with user needs and tested preferences
- Technically feasible using local CNC methods
- Visually appropriate based on cultural and persona-based testing
- Ready for pilot production in resource-limited environments

All findings form this research directly informed the final design phase and detailed housing development.

No.	Requirement	Explanation
1.1	Real-time Data Display	Interface must provide real-time insights into solar energy output of the system.
1.2	Reliability	Must function reliably over long-term use with minimal malfunction
1.3	Energy Efficiency	The product must be energy-efficient, and the design must be sustainably produced
1.4	Integration with other systems	The design must be compatible with smart energy meters and other technologies that may be relevant in the future.
1.5	Scalability	The product must be scalable within the existing infrastructure of Biosphere Solar, so it can be implemented on a larger scale
1.6	Support for Future Developments	The design must allow for future technological expansions.
1.7	Ease of Maintenance	The system must facilitate easy maintenance
1.8	Edge computing ready	Capable of processing data locally.
1.9	Weatherproof	Suitable for outdoor conditions.
2.1	Intuitive user interface	No technical knowledge required; interaction must be intuitive.
2.2	Motivation for Sustainable Living	Should stimulate energy awareness via visual cures and reminders
2.3	Aesthetics Integration	Must aesthetically blend into home or work environments.
2.4	Usability	Must remain simple and understandable; no manual required.
2.5	Trust in Information	Must display data that users consider reliable and clear.
2.6	Aesthetic requirements	Must be visually appealing, discreet, and available in multiple form options.
2.7	Theft proof	Must be tamper-resistant and unattractive for thieves
3.1	Circular Design	Design must allow recyclability and reuse of materials.
3.2	Energy Efficiency	Device must consume minimal power, even in idle mode.
4.1	Comparison with Others	Must enable users to compare their performance with peers.
4.2	Encouraging Behavioural Change	Must nudge users toward positive behavioural change.
5.1	Locally Manufacturable	Housing must be CNC-machinable in low-tech setting.
5.2	Cost-Efficient	Materials and production must fit the limited project budget.
5.3	Modular Design	Key parts such as screen and battery must be replaceable.
5.4	Persona-Based Colour fit	Colour scheme must align with tested persona preferences.
5.5	Pilot Production Compatibility	Design must be manufacturable without injection moulding.

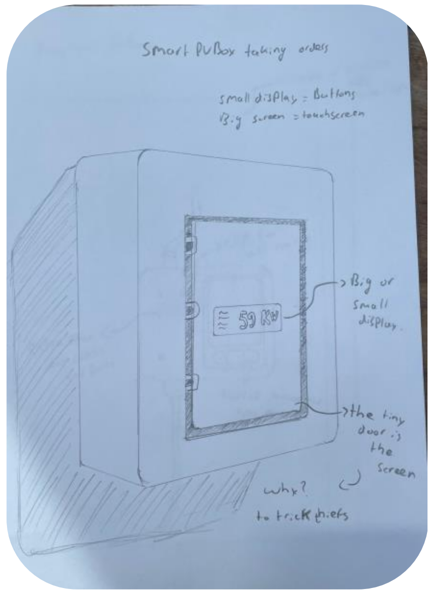
Design loops Ideation phase (design direction)

Figure 10
2 component PV Box



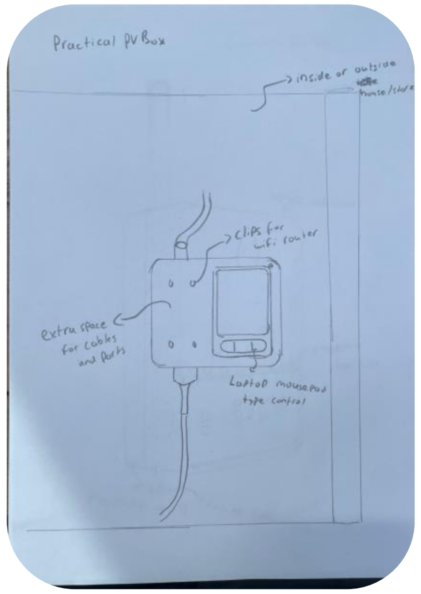
Split controller and power unit

Figure 11
SmartSafe



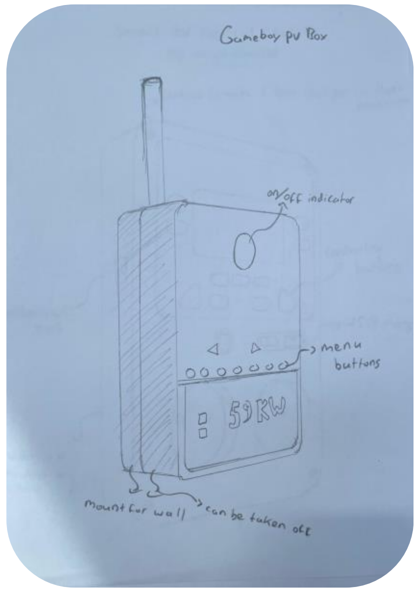
Display atop tamper-proof safe

Figure 12
Practical PV Box



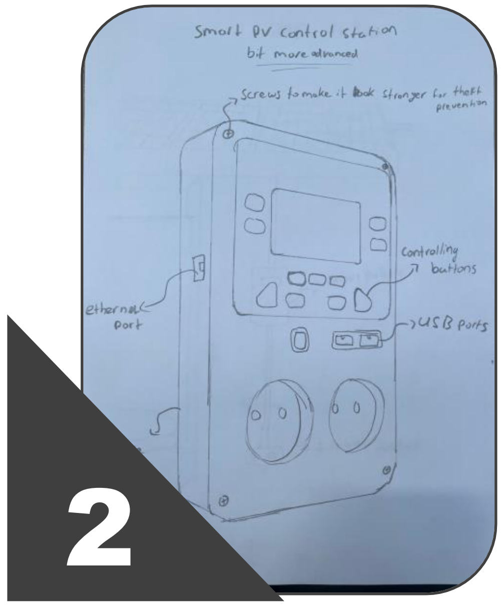
Supports stacking other devices

Figure 13
Gameboy PV Box



Retro buttons mimic arcade controls

Figure 14
Smart PV Controller



Wall mount tablet style interface

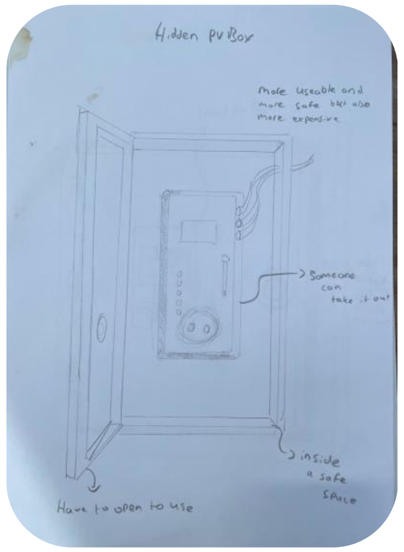
Figure 15
Easymode PV Box

Icon buttons, text-free use

After a joint review with the technical team and two representative users, three ideas- Figure 19 Figure 14 and Figure 10- were selected for further concept development.

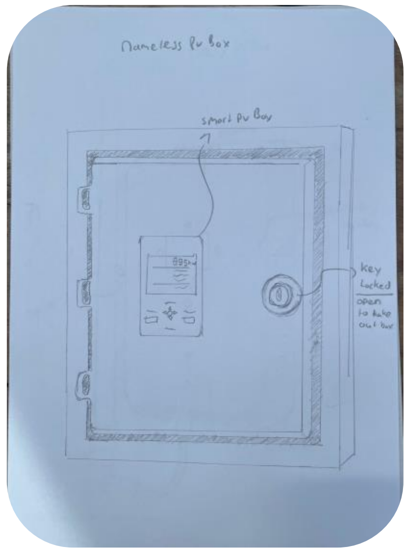
Appendix 5 summarises all chosen ideas and the selection rationale.

Figure 16
Hidden PV Box



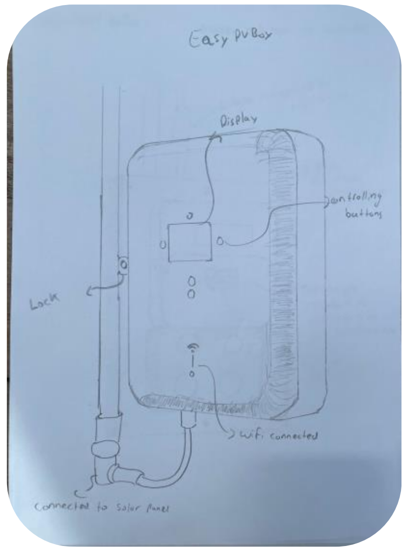
Concealed inside hinged cabinet

Figure 17
Standalone Cabinet



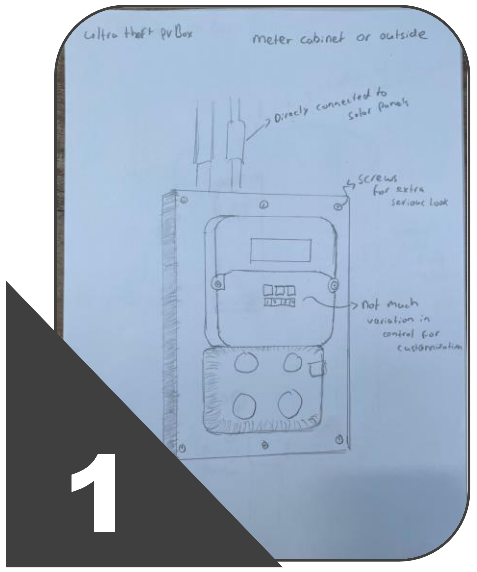
Compact, self-contained meter

Figure 18
Easy-Lock Box



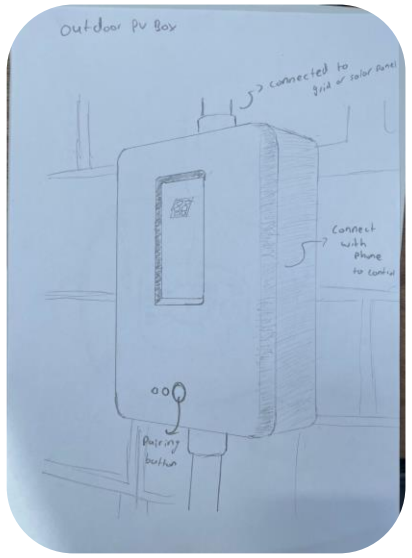
Pipe-mounted with arrow navigation

Figure 19
Anti-Theft Wall Box

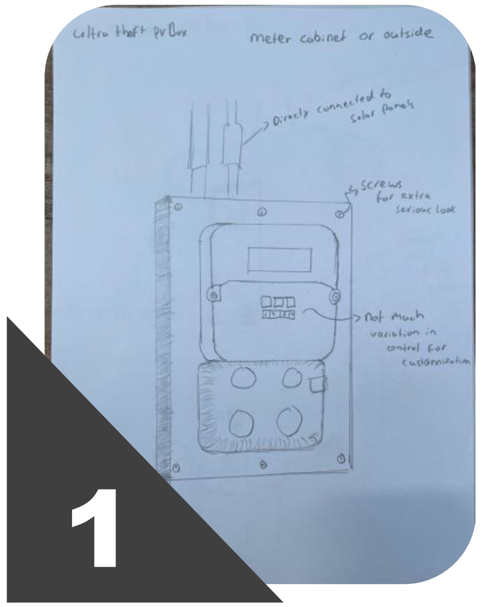


Fixed unit, deterrent screws

Figure 20
Indoor-Outdoor PV Box



Weatherproof, Bluetooth phone control



Name: Wall-Mounted Display Unit
Requirements:
- Fixed screen
- Four buttons for navigation
- Low learning curve
- Wall mountable

Figure 21
3D model render concept 1

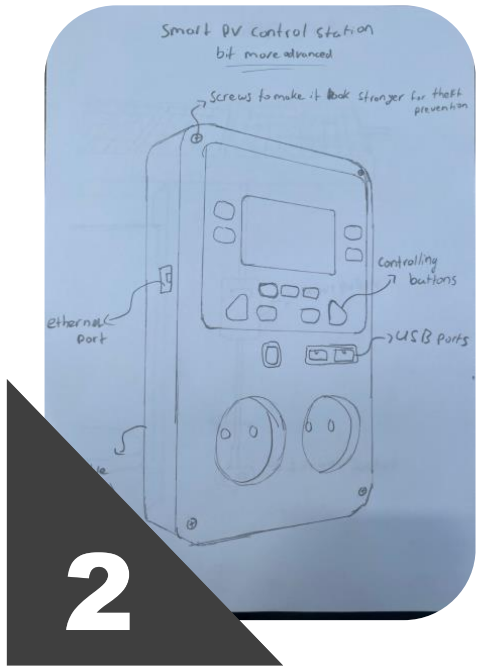
Figure 22
3D printed model of concept 1

Key facts & Verdict
User feedback (5 participants): Looks easy to install
Team feedback: Best for direct mains integration
Manufacturability: ABS Housing; screw mount; cost €25 prototype

See Appendix 6.1 for complete Concept 1 files

Selection criteria

Habit building:	–
Cost target:	√
Locally producible:	–
Digital-literacy :	√



Name: Portable Display Unit
Requirements:
- Carry or mount
- Playful
- Battery-powered

Figure 23
3D model render concept 2

Figure 24
3D printed model of concept 2

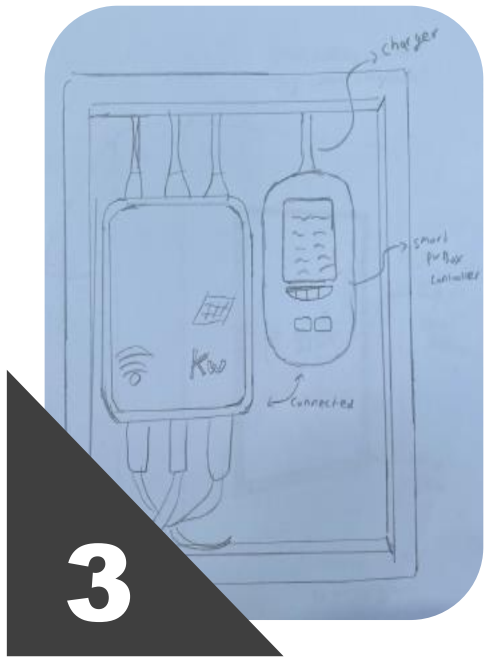
Key facts & Verdict
User feedback (5 participants): 60% likes size 40% want smaller
Team feedback: Portability questioned; screen too small
Manufacturability: Battery + Rubber edges; cost €25 prototype

See Appendix 6.2 for complete Concept 2 files

Selection criteria

Habit building:	X
Cost target:	√
Locally producible:	–
Digital-literacy :	–

Simplest UX, lowest cost, easiest to pilot



Name: Display-free Awareness module
Requirements:
- Minimalist display-free
- LED Feedback
- Phone app optional

Figure 25
3D model render concept 3

Figure 26
3D printed model of concept 3

Selected

Key facts & Verdict
User feedback (5 participants): Most preferred; magnet mount split 2/3
Team feedback: Best match to brief; cautious about Wi-Fi need
Manufacturability: Single-shell PLA; fastest CNC Cyle; cost €15 prototype

See Appendix 6.3 for complete Concept 3 files

Selection criteria

Habit building:	√
Cost target:	√
Locally producible:	√
Digital-literacy :	√

See Appendix 6.4 for Side-by-Side Comparison
See Appendix 6.5 for Design Validation and Conclusion

Figure 27
Top-view photo of parts-in-bucket (Pi, PSU, RS-485)

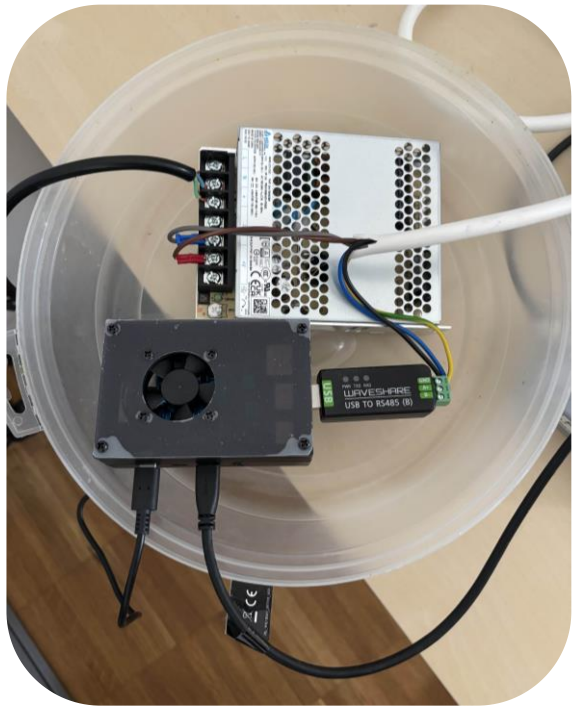
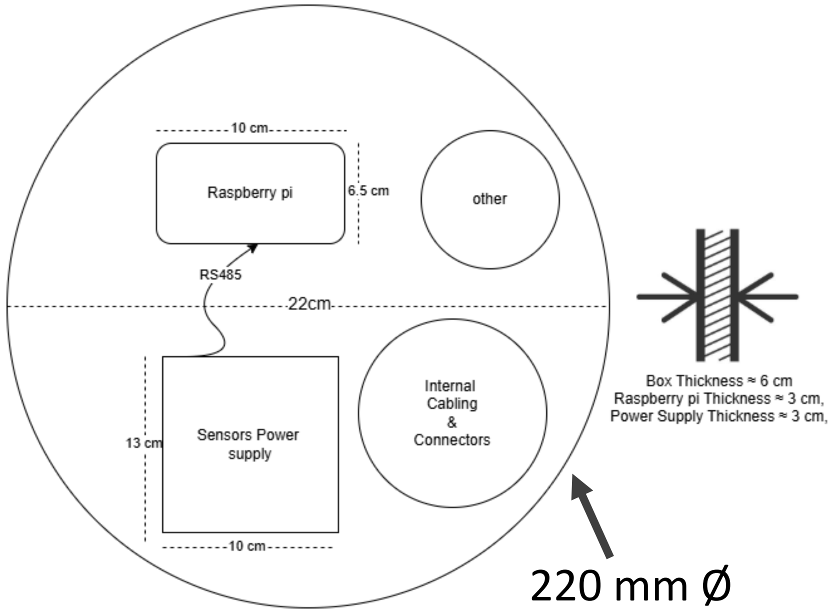


Figure 28
Top-down 2-D layout drawing (circle with labelled blocks)



1

Component sizing (Figure 27):
- Verified internal volume
- 220 mm Ø gives 15mm head-room for future add-ons.

Footprint drawing (Figure 28):
Confirmed clearance around Raspberry Pi , PSU and cable bends→ allows 60mm casing depth

Figure 29
Early CAD model

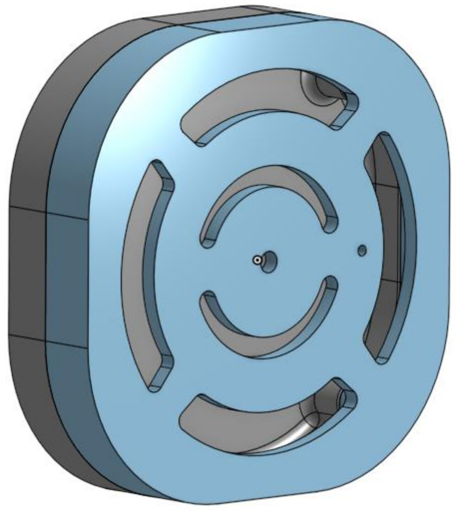
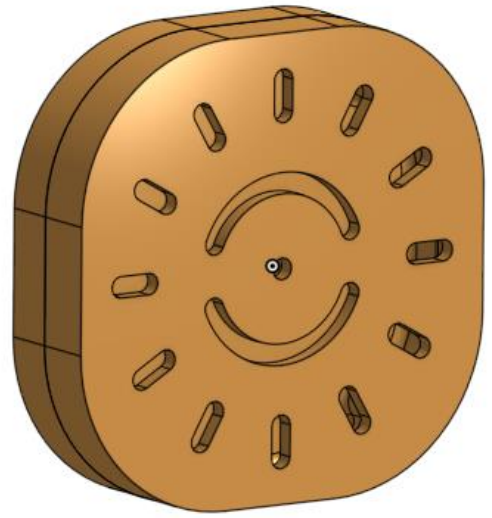


Figure 30
Revised ''sun-ray'' CAD model



2

First LED pattern (Figure 29):
- Borrowed from Concept-3 rings
- User tests: Unclear meaning + Looks like speaker

See Appendix 7 for CAD Iterations

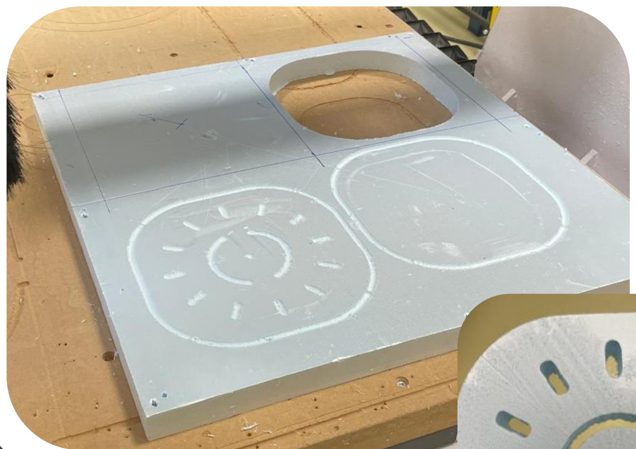
LED Sun-ray redesign:
- 12 radial slots map to energy usage
- Test users instantly recognised the sun metaphor.
- Made 2 different casing parts (one for ball nose one for flat tip cutter)

Why the sun pattern?
- Immediate metaphor: energy radiates.
- Fits circular housing; preserves wood around screw bosses.
- Allows scalable LED Count (6-24) for future models

Path dry-run
- Flat-tip toolpath verified geometry in foam
- Faster cycle + better edge accuracy than ball-nose

Machining strategy
- Flat-tip rough + finish
- Corner radius 6 mm
- Wall 8mm lip-groove 4mm

Figure 33
Foam CNC path test Flat tip vs Ball nose



Early CAD model

4

Path dry-run
- Flat-tip vs Ball nose observation
- Flat tip proved to be faster and more accurate(2)

Figure 31
Section view of curved lip-and-groove

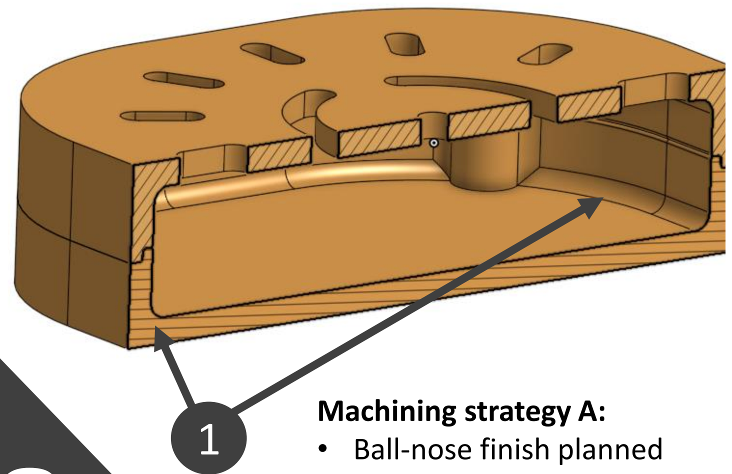
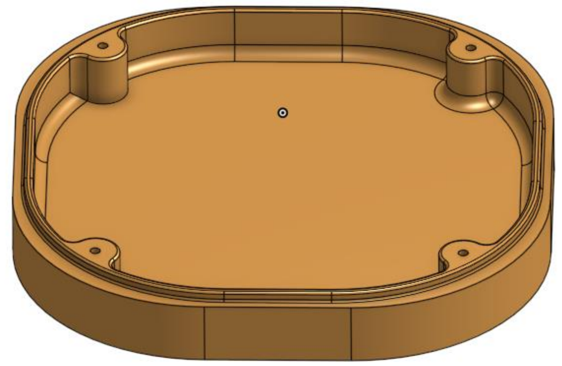


Figure 32
Bottom part of the sun-ray CAD model



3

Machining strategy A:
- Ball-nose finish planned
- Corner radius 6mm (Figure 31) (1)
- Wall8mm
- Lip 4mm (figure 32)

Figure 33
Flat-tip lip-groove test- failed

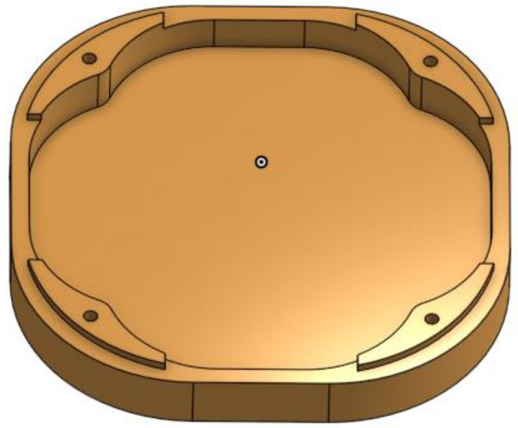
Test Flat-tip
- The 2mm lip-groove wall proved too thin and cracked during CNC machining
- Switched back to a ball-nose cutter; wall still failed

(See Appendix 9.1)

5

See Appendix 8.1 for complete process CNC prototyping

Figure 34
3D model corner-only lip-groove



Updated CAD drawing
(Fig. 8.1.5 Appendix 8.1)
- Removed all 4mm mid-walls; re-tested Corner bosses enlarged for M6 inserts; lip-groove only at corners

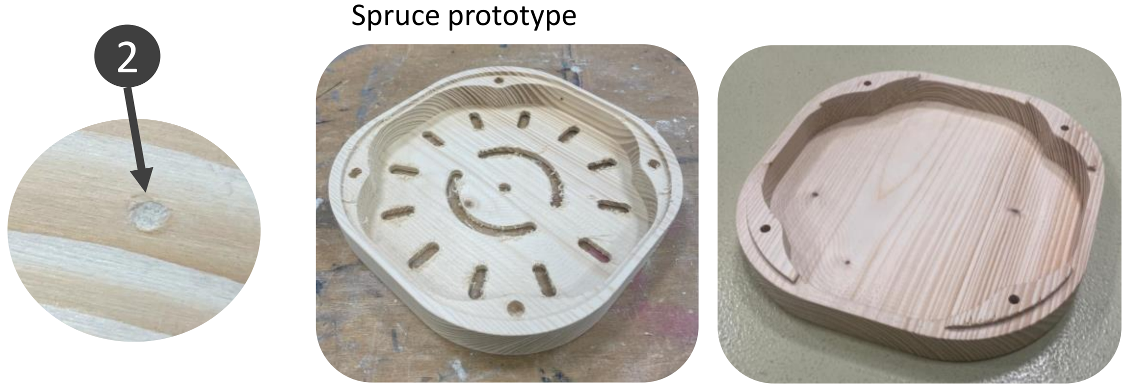
6

Figure 35
Foam mock-up confirms CAD model

Updated mock-up ✓
- Corner-only lip-groove holds 400 g load (See Appendix 9.2)
- Returned to 6mm flat-tip cutter; cycle time ↓35 %
- Wall accuracy ±0.2 mm

See Appendix 8.1 for complete process CNC prototyping

Figure 36
Spruce prototype

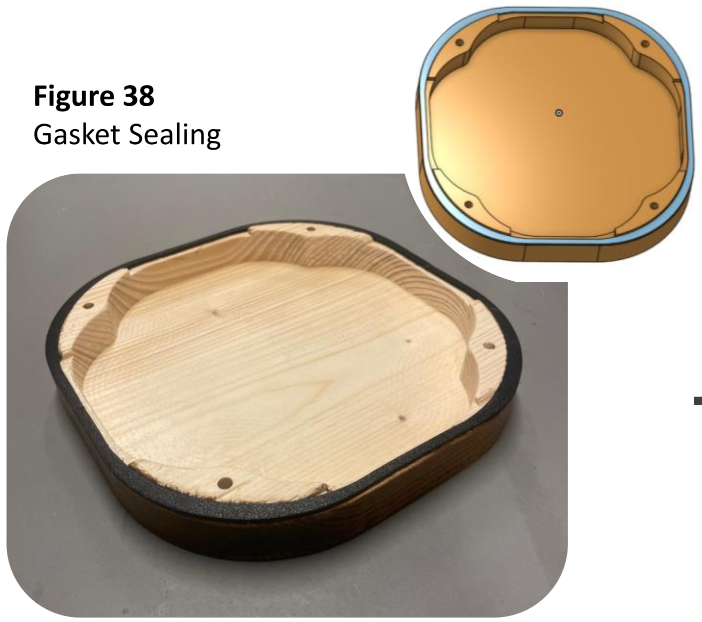


Spruce prototype
- Requires hand sanding: 120-grit, then 240-grit, before staining.
- Stainless Steel M6 threaded inserts: drill holes 1.5mm oversize. Insert did not. 12 mm of wood removed (1)
- Total CNC + hand build time ≈ **110 min**
- Small CNC tear-outs were filled with wood putty (2)

7

See Appendix 8.2 for Manual Post-Processing

Figure 38
Gasket Sealing

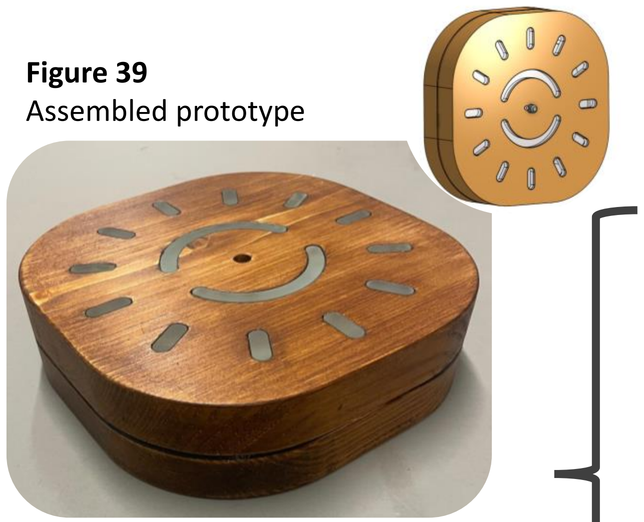


3-D printed TPU Gasket Sealing
- 0.2mm clearance between ring and housing corners

See Appendix 8.3 for Prototype Gasket Sealing

8

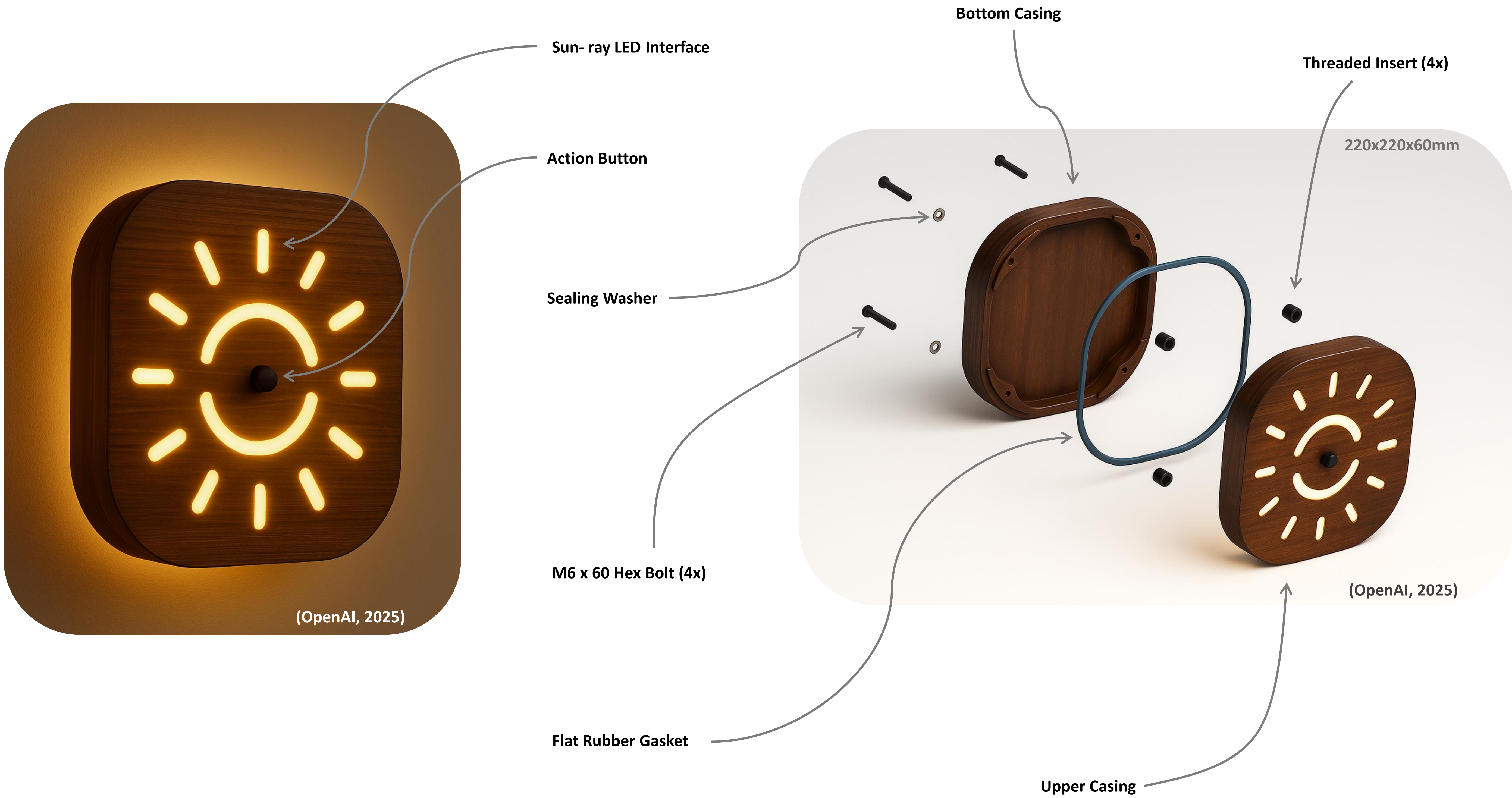
Figure 39
Assembled prototype



Pilot-ready finish
- Water-based walnut stain
- 2 coats
- Laser-cut Acrylic inserts for LED
- Assembly time < 90s

See Appendix 8.4 for Full Prototype Assembly

9



See Appendix 9.1 for Exploded view & BOM
See Appendix 9.2 for Prototype Cost price & Supplier links

Smart PV Box – Instant Solar Awareness

Pilot units ready for field test → Contact Biosphere Solar

Zero-learning interface
No menu. After a one-time pairing, all functions run automatically

Instant solar feedback
LED Sun-ray fills as panels generate power and drains while energy is used

Local, low-cost build
• CNC-milled spruce housing
• Assembly <90 s
• Total cost ≈ €11,70

See Appendix 10 for Final Product

To what extent is the design goal met?
The Smart PV Box now satisfies four of the five project goals: it reinforces a weekly habit loop, issues timely triggers when needed, requires zero learning after first time use, and can be built locally from spruce with low-tech CNC tools. The revised housing is dimensioned for an IP54 gasket clamp, CNC machining and hand finishing take roughly 110 minutes, and on-site assembly stays under 90 seconds- making a small pilot batch both realistic and affordable.

Remaining gap
Several risks still need validation. Long-term durability in tropical humidity and the product's overall water resistance have not yet been proven. Outdoor visibility in full sun is untested, the final wall-mount system is still conceptual, and the charging port must be positioned to match the battery's fixed location inside the case.

Recommendations for Biosphere Solar
- Pilot test five units in Nigeria & Brazil- both urban and rural- over eight weeks and log daily user interaction.
- Investigate regionally sourced wood to reduce shipping-related CO2

Wall-mount solution
The prototype still needs a definitive mount. A magnetic bracket was rejected by test users, so a simple screen-on cradle should be developed and verified by loading the Smart PV Box with weights until failure; the resulting factor of safety can then be added to the pilot specification.

Mounting kit validation
A prototype screw-on cradle made from 2mm stainless strip should be trial-mounted on both solid masonry and 12mm plywood, stimulating rural and urban walls. By filling the Smart PV Box with 1kg weight and applying 45° downward pull for sixty seconds, the team can certify a safety factor of three over worst-case cable loads.

Production run > 1000 units
If demand exceeds a thousand units, the CAD model must be re-engineered for injection moulding. Wall thicknesses could drop to 1.8mm instead of the current 6-8mm, creating extra interior volume but also requiring ribs and bosses for stiffness. Gate placement, draft angles and ejector-pin landings should be added, and the lip-groove redesigned for two-shot over moulding.

Finish durability
Although two coats of water-based walnut stain protect the spruce, the surface still needs an abrasion check. A simple rub test will show whether the pigment or the underlying grain fuzzes after daily cleaning. Should micro-scratching appear, a third clear coat with hardener can be added without altering colour or dry-time.

UV and moisture ageing
The pilot batch should include one sacrificial enclosure that spends eight weeks on a rooftop in direct equatorial sun and nightly dew. Weekly observations will show if there is any swelling, and UV fade. It must be figured out whether users need to re-oil the housing annually or every second year.

Files and hand-over
All 3-D models, technical drawings, assemblies and exploded views have been consolidated in a single OnShape project. Siemen Brinksma already has access and can export neutral STEP files or native OnShape packages directly into the Biosphere Solar vault.

Closing statement
The Smart PV Box demonstrates that a low-cost, instantly readable interface can nudge households in the Global South toward more efficient solar-energy use. With four core goals achieved, a clear path to IP-54 validation, and a bill-of-materials close to target cost, the product is ready for field trials. By executing the recommended wall-mount redesign, environmental testing and PCB consolidation, Biosphere Solar can move confidently from pilot batch to scalable production- turning a functional prototype into a durable, locally manufacturable energy-awareness solution.


Render of the prototype (OpenAI, 2025)

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