Thera-Hand Life Cycle Assessment

The Life Cycle Assessment (LCA) evaluates the environmental impact of the Thera-Hand rehabilitation device across its entire life cycle. This includes material extraction, manufacturing, use, and disposal/recycling.

1. Goal and Scope Definition

Objective:

The LCA aims to assess the environmental footprint of the Thera-Hand rehabilitation device, considering its:

- Energy consumption (power supply, servos, ESP32).
- Material usage (PLA, rubber, fishing line, sensors).
- Manufacturing and transportation impact.
- End-of-life disposal/recycling feasibility.

Functional Unit:

A single Thera-Hand device is assumed to be used for 2 years before replacement.

System Boundaries:

This LCA includes:

✅ Raw Material Extraction – Plastics, rubber, and electronics production.
✅ Manufacturing & Assembly – 3D printing, PCB production, servo motor production.
✅ Transportation – From manufacturing to users.
✅ Use Phase – Power consumption during operation.
✅ End of Life – Disposal, recycling, or potential reuse.

2. Inventory Analysis

Material Composition & Impact

Component	Material	Environmental Impact
Frame & Housing	PLA (3D printed)	Low-carbon footprint, biodegradable under specific conditions
Sensors	Flexible PCB, resistive materials	Electronic waste, difficult to recycle
Actuators (Servos)	Plastic, copper wiring	High-energy manufacturing, limited recyclability
Power Supply	Electronic components, metal	Requires responsible e-waste disposal
Wiring & Fishing Line	Copper wiring, nylon	Small footprint, but non-biodegradable

Energy Consumption (Use Phase)

Based on prior power consumption estimates:

Component	Power Consumption (W)	Usage per day (hours)	Annual Energy (kWh)
ESP32	1.25W	2	0.91 kWh
5 SG90 Servos	6.25W (idle) / 16.25W (peak)	1	5.93 kWh
Sensors & LED	0.15W	2	0.11 kWh
Total Estimate	≈ 7.65W - 17.65W	-	6-7 kWh/year

- Comparison: This is equivalent to a low-power LED bulb running for ~3 months.

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3. Impact Assessment

Environmental Hotspots

🔴 Manufacturing:

- Electronics production (ESP32, sensors, servos) has the highest carbon footprint.
- 3D printing (PLA) requires energy but has a relatively low impact compared to metals.

🟡 Use Phase:

- Low electricity consumption (~6-7 kWh/year) makes it energy-efficient.

🟢 End-of-Life Considerations:

- PLA parts are biodegradable in industrial composting but not in landfills.
- Servos, wiring, and PCBs require responsible e-waste recycling.

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4. Interpretation & Recommendations

Key Findings

✅ Low Energy Consumption: Thera-Hand is energy-efficient in use.
✅ Minimal Carbon Footprint for PLA: The frame is eco-friendly, but plastics must be disposed of properly.
⚠️ E-Waste Challenge: Sensors, servos, and the ESP32 must be recycled properly.
⚠️ Transportation Impact: If shipped globally, the CO_2 footprint increases.

Recommendations

✅ Optimize 3D Printing Material:

- Use recycled PLA or biodegradable TPU to reduce waste.

✅ E-Waste Collection Plan:

- Offer a recycling take-back program for electronics.

✅ Reduce Servo Impact:

- Use low-power or energy-efficient servos if possible.

✅ Sustainable Packaging:

- Use biodegradable or recycled materials for packaging.

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5. Conclusion

- Thera-Hand is a low-energy, partially sustainable device.
- The biggest environmental concern is e-waste disposal of sensors & servos.
- Efforts to recycle electronic components and use sustainable materials can improve its eco-friendliness.