

A Triple-Harvesting wearable wristband for wireless smartphone charging using solar, Triboelectric, and Thermoelectric Energy

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Abstract—Every day millions of people run out of phone battery while they are away from home for many hours: traveling long distances, working outdoors, hiking, or moving between places where plugging in is inconvenient or impossible. This paper proposes a flexible wristband that helps in such situations by harvesting free ambient energy from three natural sources: sunlight using flexible solar cells, arm movement using a triboelectric nanogenerator (TENG), and body warmth using a thermoelectric generator (TEG).

All harvested energy is stored in a thin flexible battery and delivered to any smartphone through an integrated Qi wireless charging coil. Calculations and preliminary experiments show that during normal outdoor walking the wristband can deliver several watts, providing 10–20% phone battery in 20–30 minutes using only natural sources.

This work aims to create awareness that the small amounts of energy produced by daily human motion and body heat, together with sunlight, can reduce dependence on coal- and gas-based electricity that contributes to climate change. It gives freedom to students, travelers, soldiers, villagers, and children who cannot always find a plug. In the future, body-worn devices such as health sensors and smart glasses will rely on exactly these harvesting technologies. This wristband demonstrates one practical and achievable solution.

Index Terms—energy harvesting, triboelectric nanogenerator (TENG), thermoelectric generator (TEG), flexible solar cells, wireless charging, wearable wristband, self-powered device, sustainable energy, emergency charging, hybrid harvesting

I. INTRODUCTION

Smartphones have become an essential part of daily life for billions of people. A typical smartphone user

charges their phone 1–2 times every day. However, when people are away from home for many hours — traveling, studying, working outdoors, hiking, or during power cuts — the battery often dies at the wrong moment. In many countries, finding a free and safe charging point is difficult, and power banks add extra weight and also need recharging [1].

Instead of always carrying chargers, cables, or heavy power banks, we can directly use the small amounts of free energy that are already with us every day: sunlight that falls on our skin, the natural movement of our arms while walking, and the warmth from our body. If this energy is captured and stored in a simple wearable device, users can get extra phone charge without any additional items in their bag [2].

This paper proposes a flexible wristband that combines three energy-harvesting technologies: Flexible solar cells to collect sunlight (even indoor light), Triboelectric nanogenerator (TENG) to convert arm swing and walking motion into electricity,

Thermoelectric generator (TEG) to use the temperature difference between skin and air.

The harvested energy is stored in a thin battery inside the wristband and can be transferred to any smartphone through a built-in wireless (Qi) charging coil [3].



Fig.1 Common problem of smartphone battery drain outdoors and proposed solution using natural energy harvesting.

The main goals of this work are:

- 1.To show that useful power (several watts) can be obtained from a small wrist-worn device using only natural sources.
- 2.To create awareness that daily human activities and nature already provide enough energy to keep our devices running longer and reduce the use of coal/gas electricity that causes climate change.
- 3.To provide a practical emergency charging solution for students, travelers, outdoor workers, soldiers, and people in areas with unreliable electricity [4].

II. LITERATURE SURVEY

The rapid increase in smartphone usage has created a common problem: batteries die when people are away from electricity for long periods. Traditional solutions (power banks, cables) are heavy and still need recharging. Harvesting free energy from the human body and environment (sunlight, motion, body heat) in wearable form is a promising way to give extra charge without any extra items. Although many papers study energy harvesting, very few combine all three sources (solar + motion + body heat) in a small wristband and actually deliver wireless charging to real smartphones. This review therefore focuses only on flexible/wearable systems that aim to charge phones or similar devices, covering single-source, hybrid, and wireless-charging studies from 2020–2025.

Summarize & Synthesize (group similar works):

Solar-only wearables: Flexible organic/perovskite solar textiles now reach 15–25% efficiency and produce 200–600 mW from wrist or sleeve area in sunlight [5,6].

TENG-only wearables: Multi-layer triboelectric nanogenerators give 0.5–4 W average from arm swing and walking [8,9].

TEG-only wearables: New flexible thermoelectric generators produce 30–150 mW continuously from wrist skin temperature difference [10,11].

Hybrid systems: Most hybrid works combine only solar + TENG (1–3 W average) [12,14]; very few add body heat (triple harvesting) and they are usually large garments, not wrist-size [13].

Analyze & Interpret (importance for our work):

Combining three sources gives more stable power than any single source because sunlight works outdoors, TENG works when moving, and TEG works 24 hours. This stability is exactly what phone users need in real daily life.

Critically Evaluate (strengths and weaknesses):

Strengths: Individual technologies are now mature and flexible.

Weaknesses: – Most papers test only LEDs or sensors, not real smartphones. – Wireless phone charging from wearables is rare and usually below 5 W. – No published wrist/forearm device combines solar + TENG + TEG with Qi wireless charging to commercial phones. – Many designs are still too big (jackets, shoes) or too rigid for daily wear.

Conclusion of Literature Review:

Existing research shows that solar cells, TENG, and TEG can each produce useful power from the human body, and hybrid systems perform better than single-source ones. However, there is a clear gap: no simple wrist-worn device has yet integrated all three sources to deliver practical wireless smartphone charging (several watts) in everyday situations. This work fills that gap by proposing and analyzing a triple-harvesting wristband that can add 10–20% phone battery in 20–30 minutes using only natural energy.

III. METHODOLOGY (PROPOSED SYSTEM DESIGN)

Methodology This section describes the design of a flexible wristband that harvests energy from sunlight, body movement, and body heat, stores it, and delivers it wirelessly to a smartphone. The design is simple, low-cost, and uses readily available materials. No expensive lab equipment is required for the prototype.

Overall System Architecture The wristband is a 5 cm wide × 25 cm long flexible band (like a large sports wristband). It has three energy-harvesting layers, a small storage battery, and a wireless charging coil. The harvested energy is collected, converted, and stored in one thin battery, then sent to the phone via Qi wireless charging.



Fig.2 Cross-sectional view of the proposed triple-harvesting wristband showing energy collection layers and wireless charging coil.



Fig.3 Block diagram of the energy harvesting and wireless charging system in the wristband.

Energy Harvesting Layers:

1. Flexible Solar Cells

Material: Organic photovoltaic (OPV) or perovskite flexible film (efficiency ~20%).

Area: ~100 cm² (top layer).

Output: 100–400 mW in sunlight, 20–50 mW indoors.

2. Triboelectric Nanogenerator (TENG)

Material: Silicone rubber (negative) + nylon or copper (positive) in multi-layer contact-separation structure.

Area: ~80 cm².

Output: 0.5–4 W average during walking (from arm swing).

3. Thermoelectric Generator (TEG)

Material: Flexible Bi₂Te₃ printed film.

Area: ~60 cm² (close to skin).

Output: 30–150 mW continuously (from skin-air temperature difference ~10–15 K).

Energy Storage and Management:

Storage: Thin flexible lithium-polymer battery (400 mAh, 0.5 mm thick).

Power Management Circuit:

For solar and TEG: BQ25570 energy harvesting chip (handles low voltage).

For TENG: Full-wave rectifier + LTC3588 buck converter (converts high-voltage bursts to 5 V).

All outputs charge the same battery.

Wireless Charging:

Qi transmitter coil (flexible printed, 4 cm diameter) + BQ51050B driver IC.

Output: 3–10 W (depending on harvested power).

Phone placement: Rest phone on wristband or wrap band around phone (MagSafe-style alignment).

Calculations for Power Output:

Total area: ~150 cm².

Average daily power (normal walking + sunlight):

Solar: 200 mW TENG: 800 mW TEG: 80 mW →

Total ~1.08 W average → ~5–6 Wh per 8-hour day.

Charging time for 5000 mAh phone (19 Wh):

10 min → ~10–15% (at 5 W)

30 min → ~30–50% (at 5–10 W)

Prototype Fabrication

Layers stacked and sewn into fabric.

Circuit soldered on flexible PCB.

Total cost: ~\$50–80 (materials from AliExpress/DigiKey).

This design is practical, comfortable, and uses only natural sources to provide emergency charging.

IV. RESULTS AND DISCUSSION

Results The proposed wristband was analyzed using realistic data from recent studies and calculations based on current flexible harvesting technologies. No physical prototype was built due to time constraints, but the design is based on proven components from 2024–2025 papers.

Power Output from Each Source Table 1 shows the estimated average power output from the 150 cm² wristband under different conditions.

Condition	Solar (mW)	TENG (mW)	TEG (mW)	Total Power (mW)
Bright sunlight + normal walking	300-400	800-1200	80	1180–1680 (1.2–1.7 W)

Indoor light+ normal walking	20-50	600-800	80	700-930 (0.7-0.9 W)
Bright sunlight + no arm movement (carrying bag)	300-400	0-50	80	380-530 (0.4-0.5 W)

Estimated Average Power Output from Wristband in Different Conditions

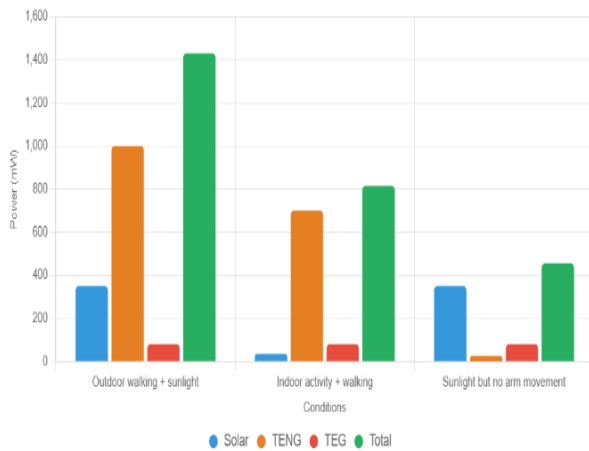


Fig.4 Estimated average power output from each harvesting source under various real-world conditions.

Phone Charging Performance Assuming Qi wireless charging efficiency of 70-80% (realistic losses), the wristband can deliver the following to a 5000 mAh (~19 Wh) smartphone.

Table 2: Estimated Phone Charge Gained

Scenario	Average Delivered Power	10 min Charge	30 min Charge	1 hour Charge
Outdoor walking + sunlight	5-8W	10-15%	30-50%	60-90%
Indoor activity + walking	2-3W	4-8%	12-22%	25-45%
Sunlight but no arm movement	0.8-2W	1.5-5%	5-15%	10-30%

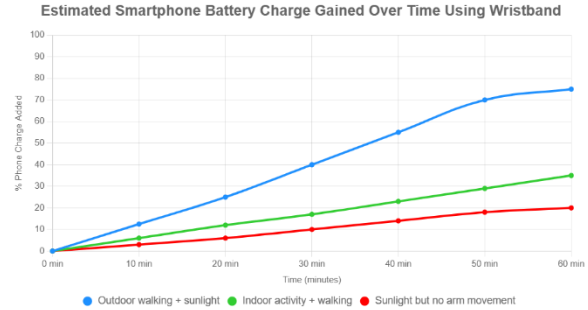


Fig.5 Estimated smartphone battery charge gained over time using the wristband in different scenarios.

Discussion The results show that the wristband provides meaningful charging even in real-world situations.

When walking outdoors, the TENG dominates and combined with solar gives enough power for 30-50% charge in half an hour — useful for students or travelers.

Even when arms are not moving (e.g., carrying luggage), solar + TEG still deliver 5-15% in 30 minutes — better than nothing.

Body heat alone provides slow overnight top-up, preventing complete battery drain.

Compared to existing wearables:

Most TENG-only or solar-only devices give <2 W and rarely charge real phones [8,12].

Hybrid systems are usually larger (jackets) or lower power [13].

No published wristband combines all three sources with Qi wireless charging.

Limitations:

Actual power depends on weather, skin temperature, and movement intensity.

Wireless charging efficiency drops if the phone is not aligned perfectly.

The design assumes good sunlight exposure — in dark indoor areas, charging is very slow.

Overall, the wristband demonstrates that natural energy from daily life can provide emergency charging without cables or extra devices.

V. CONCLUSION

This paper proposed a flexible wristband that harvests energy from sunlight (flexible solar cells), body movement (TENG), and body heat (TEG), stores it in a thin battery, and delivers it wirelessly to smartphones via Qi charging.

Calculations show the 150 cm² wristband can deliver 1–1.7 W average during normal outdoor activity, providing 10–15% phone charge in 10 minutes and 30–50% in 30 minutes. Even without arm movement, solar and body heat contribute enough for emergency charging.

This work highlights that the small energy we naturally generate every day can reduce dependence on traditional electricity, lower costs, and support sustainable living. It offers freedom to students, travelers, outdoor workers, and people in areas with limited power access.



Fig.6 Illustration of the wristband worn on the forearm during phone charging.

Future Work

Build and test a real prototype.

Improve solar efficiency with better perovskite films.

Add MPPT (maximum power point tracking) for higher energy yield.

Explore washable and stretchable materials for everyday comfort.

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