MedCrave
Step into the World of Research
Journal of Textile Engineering & Fashion Technology

Opinion

Open Access
CrossMark

Energy harvesting textiles – a look at selected textile-based energy harvesting approaches of the last decade

Abstract

Energy harvesting textiles represent a truly transformative development in the area of wearable smart textiles. These integrate renewable energy technologies—photovoltaic, piezoelectric, thermoelectric, and triboelectric systems—directly into fabrics to autonomously power low-power devices. Each harvesting principle brings unique advantages and limitations -- photovoltaic systems provide high energy output under light but face challenges in flexibility and washability; piezoelectric and triboelectric systems excel in capturing motion-induced energy but deliver low power densities; thermoelectric materials harness body heat, but the efficiency remains low. Recent advances in hybrid textile architectures demonstrate the feasibility of combining these principles within a single structure, using flexible materials like PVDF, PEDOT:PSS, CNTs, and MXenes. These hybrids show improved performance via energy complementation, especially when integrated using scalable techniques such as electrospinning, fiber coating, or embroidery.

Commercial viability of the systems remains somewhat poor by challenges in terms of scalability, energy density, mechanical durability, and washability. Compared to commercial batteries, current textile systems provide significantly lower energy outputs, suitable primarily for intermittent or low-demand applications such as biometric sensors or IoT wearables. Promising solutions include encapsulation techniques, electrospun nanofiber coatings, and the integration of energy storage units like supercapacitors. Several studies have demonstrated wash-resistant designs that maintain functionality across multiple laundry cycles, marking a critical step toward real-world adoption. While the field is still evolving, the convergence of material innovation, smart integration, and textile engineering is rapidly pushing energy harvesting textiles closer to practical reality.

Keywords: photovoltaic, piezoelectric, thermoelectric, triboelectric, nano-generator, scalability, energy density

Volume 11 Issue 4 - 2025

Radhakrishnaiah Parachuru,[1] Vivek A Ganti[2]
[1]Principal Research Scientist -Emeritus Status, MSE, Georgia Institute of Technology, Atlanta, USA
[2]Entrepreneur Currently Operating in Silicon Valley, California

Correspondence: Radhakrishnaiah Parachuru, PhD, MSE, Principal Research Scientist -Emeritus Status, Georgia Institute of Technology, MSE, Atlanta, GA, USA

Received: August 08, 2025 | **Published:** August 22, 2025

Introduction

Textiles are being dramatically repurposed as energy-harvesting power plants using solar fabrics to capture sunlight,[1,2] and also by using triboelectric and piezoelectric textiles to capture motion.[3–5] Solar fabrics are embedded with flexible PV cells—either woven into fibers or coated on surfaces—to turn outer garments into mini-solar farms. The PV cells range from thin-film or organic polymer-based PVs to the futuristic perovskite tech and photoanode-woven hybrids. Contemporary overviews dive into the ins and outs of these photovoltaic textiles, detailing how to maintain flexibility, washability, and durability in wearable gear. Kinetic, thermal, and RF energy sources are being exploited with next-generation textile technology. Triboelectric nanogenerators (TENGs) and piezoelectric fabrics capture motion when people wearing garments walk or when rain drops fall on fabrics; the captured mechanical energy is converted to power. There are dual-action fabrics: solar plus triboelectric, similar to the Georgia Tech fabric that charges a capacitor in just a minute using sunlight and motion. Thermal and RF harvesting are also being practiced.[6,7] Piezo-thermo "dual envelope" fabrics for Navy SEAL-style suits harvest both heat and movement, while printed textile rectennas capture ambient Wi-Fi at 2.45 GHz—on fabric.

Thus, textiles are going way beyond fashion—they are now a significant part of alternative energy generation. Progressive textile manufacturers around the globe are preparing themselves for the era of energy-harvesting fabrics, where threads don't just cover the body, but generate power.

Categories of energy harvesting textiles and how they work

The selection of piezoelectric, triboelectric, thermoelectric, and photovoltaic energy harvesting techniques for textile integration is driven by their ability to exploit diverse ambient energy sources—mechanical motion, body heat, and sunlight which are commonly encountered in wearable contexts. These principles are inherently low-profile, scalable, and fiber-compatible, making them suitable for incorporation into fabrics without compromising comfort or flexibility. Moreover, each technique complements the others - piezoelectric and triboelectric harvest intermittent motion, thermoelectric captures continuous thermal gradients, and photovoltaic provides daytime power, collectively enabling hybrid systems that ensure more consistent and sustainable energy supply for wearables.

Photovoltaic (Solar) textiles

What it is: Fabrics integrated with flexible solar cells or photovoltaic fibers

How it works: These textiles capture sunlight and convert it into electricity.

Examples:

a) Solar-powered jackets & backpacks: Charge phones and devices on the go. These can be thought of as portable charging stations that also serve other traditional functions.

Submit Manuscript | http://medcraveonline.com

©2025 Parachuru et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and build upon your work non-commercially.

Copyright: ©2025 Parachuru et al.

b) Solar tents: Used in military or disaster zones to power communication devices.

c) Curtains and window shades with built-in PV fibers: Collect solar energy indoors.

Technology behind it:

i. Organic PV cells

ii. Thin-film silicon

iii. Dye-sensitized solar cells woven into fibers (Figure 1)

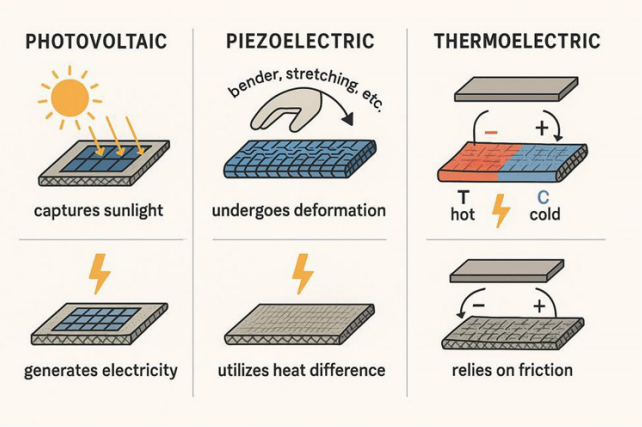

Figure 1 Pictorial illustration of three main categories.

Piezoelectric textiles

What it is: Fabrics embedded with piezoelectric materials (like ZnO nanowires) that generate electricity when bent, stretched, or pressed.

How it works: Converts mechanical stress into electric charge.

Examples:

a. Smart shoes or insoles: Generate power from footsteps to charge small electronics or sensors.

b. Military uniforms: Harvest kinetic energy from soldier movements.

c. Wearable tech: Power sensors that monitor health or motion.

Fact: A jogging outfit could one day power a smartwatch, thus eliminating the need to separately charge the smart watch.

Thermoelectric textiles

What it is: Fabrics that exploit the Seebeck effect—converting heat gradients into electricity

How it works: When one side of the fabric is warmer than the other, electrons flow and generate power.

Examples:

A. Wearables: Use body heat to power fitness trackers or emergency beacons.

B. Heated car seats: Recover waste body heat and convert it back into usable energy.

Common materials: Bismuth telluride, carbon nanotubes + conductive polymers

Triboelectric Nanogenerator (TENG) textiles

What it is: These use the triboelectric effect—basically static electricity generation by friction between two materials

How it works: Fabrics rub against each other or your body, creating a charge.

Examples:

a) Energy-harvesting sportswear: Generate power while you move.

b) Backpacks: Capture energy as you walk or run.

c) Seat covers in vehicles: Harness human movement to power ambient lights.

Hybrid textiles

What it is: Textiles that combine multiple energy sources—solar, kinetic, thermal—for maximum output

Example: A single fabric made with:

i. Photovoltaic yarns (for sunlight),

ii. Piezoelectric nanofibers (for motion),

iii. Thermoelectric layers (for body heat)

These are being explored for off-grid wearables, disaster relief clothing, or self-sustaining IoT sensors.

Key industries promoting textile-based energy harvesting

a) Defense: Smart uniforms that power communication gear

b) Sports & Fitness: Wearables that never need charging

c) Medical Tech: Self-powered health monitors

d) Aerospace & Automotive: Lightweight, flexible solar fabrics

What are some current hurdles faced by the technology

i. Durability (washing and wear resistance)

ii. Efficiency vs. traditional energy harvesters

iii. Cost of production at scale

But the momentum is building. Textile-based energy solutions are a *legit flex*—sustainable, flexible, and fashion-forward.

Design and functional requirements of textile structures produced for energy harvesting

Here is an overview of the design and functional requirements for energy-harvesting textile structures using piezoelectric, thermoelectric, photovoltaic, and triboelectric principles, along with a cost-comparison table.

Piezoelectric textiles:design & functional requirements

1) Materials: Flexible piezoelectric polymers (e.g., PVDF, PVDF–TrFE) or composites incorporating PZT or $BaTiO_3$ nanoparticles in stretchable matrices[8]

2) Structures: Fibers spun via electrospinning, yarns either braided or woven into fabrics, or laminated thin films—must endure repeated bending and maintain electrical connectivity.

3) Functional Performance:

a. Strain/pressure converts to voltage via aligned dipole domains.

b. Must produce sufficient charge under realistic deformations: typical output in μW–mW range depending on frequency & load.

c. Requires integration of electrodes and flexible wiring without disrupting textile feel.

4) Stability & Integration:

a. Durable under $>10^5$ mechanical cycles.

b. Encapsulation needed to resist moisture and washing.

c. Electrical contacts must coexist without bulkiness.

Thermoelectric textiles: design & functional requirements

1) Materials:

a. Organic thermoelectric inks (e.g., polypyrrole-coated PET) or carbon nanotube yarns

b. Inorganic nanomaterials (e.g., Bi_2Te_3, Ag_2Se) for higher zT efficiency[9]

2) Structures: Yarn-based yarns or 3D knitted/fabric structures designed to maximize ΔT between body/environment.[10]

3) Functional performance:

a. Seebeck effect transforms temperature gradients (e.g., body surface vs ambient) into voltage.

b. Power densities of tens of μW/m² with ΔT ~5°C; specialized organic textiles reach ~50 mW/m² at ΔT ~47 K

4) Requirements:

a. Structure must ensure thermal gradient: hot side contacts body, cold side interacting with air.

b. Mechanical flexibility, air breathability, and minimized thermal mass.

c. Interconnect wiring to low-power electronics and encapsulation for washability.

Photovoltaic textiles: design & functional requirements

1) Materials:

Flexible dye-sensitized, organic polymer (e.g., perovskite), CIGS thin films, or crystalline-silicon microcells on fibers[10]

2) Structures:

a. Fibers coated or embedded with PV layers, then knit/woven—also planar films laminated onto fabric

b. Functional performance:

i. Under 1 sun, flexible versions typically reach 5–12% efficiency.

ii. Fiber PV may output tens of mW per fiber; optimized perovskites are emerging[11]

3) Requirements:

i. High mechanical resilience to bending/abrasion and environmental exposure (UV, moisture).

ii. Electrical contacts and interconnects must balance conductivity & flexibility. o Surface encapsulation for transparency and durability without compromising softness.

iii. Thermal management to prevent efficiency loss at high temps.

Triboelectric textiles: design & functional requirements

1) Materials:

Pairs of triboelectric materials (e.g., PTFE, nylon) attached/coated to textile layers or fibers[12]

2) Structures:

Interlaced layers (knit, woven, braided), compressible woven TENGs, nonwoven mats—e.g., recent texTENG for DIY-friendly designs.[13]

3) Functional performance:

a. Convert motion/friction into AC via repeated contact/separation.

b. Output densities up to 312 W/m² in the lab; wearable fabrics typically produce few mW/m²

4) Requirements:

a. Structure must facilitate frequent contact cycles, maximize surface charge generation.

b. Electrode incorporation while preserving breathability and wear comfort. o Need for rectifier/capacitor modules to convert AC to usable DC.

c. Robust to wear, laundering, washing, and abrasion (Table 1).

Table 1 Cost comparison

Principle	Material cost*	Fabrication complexity	Typical power density	Estimated textile cost**
Piezoelectric	Medium ($20–50/m²)	Medium–High (electrospinning, layering)	μW–mW/m²	$25–75/m²
Thermoelectric	Medium ($15–40/m²)	Medium (ink deposition, yarn knitting)	μW–tens mW/m²	$20–60/m²
Photovoltaic	High ($50–150/m²)	High (clean environments, PV film deposition)	mW–tens mW/m²	$60–200/m²
Triboelectric	Low–Medium ($10–30/m²)	Low–Medium (weaving, coating)	mW–W/m² (lab peak)	$15–50/m²

*Raw material market prices in 2025

**Includes processing & expected scale-up margins

Citation: Parachuru R, Ganti VA. Energy harvesting textiles – a look at selected textile-based energy harvesting approaches of the last decade. *J Textile Eng Fashion Technol.* 2025;11(4):194–200. DOI: 10.15406/jteft.2025.11.00422

Copyright: ©2025 Parachuru et al.

Summary & final insights

1) Piezoelectric textiles are suited for dynamic environments where strain is frequent. Moderate cost with reliable repeatability.

2) Thermoelectric fabrics provide energy from constant heat differences—beneficial for wearables—but suffer from low ΔT and efficiency.

3) Photovoltaic integration offers high density only under good lighting; added to textile flexibility and durability, it remains the most expensive.

Triboelectric solutions offer a balance of low cost and simplicity, excelling in high-motion scenarios but with variable output.

Compatible energy harvesting combinations

Hybrid textile energy harvesting systems integrate multiple principles—piezoelectric, triboelectric, thermoelectric, and photovoltaic—to optimize power output and reliability in variable environments. By harvesting energy from diverse stimuli (motion, light, temperature difference), these systems offer sustained power generation even when one energy source is unavailable.

Piezoelectric + Triboelectric

i. Both generate electricity from mechanical deformation or motion.

ii. Can share common substrate and electrode layers.

iii. Proven synergistic performance in nanogenerator designs.

Photovoltaic + Thermoelectric

a. Photovoltaic (PV) units convert light to electricity.

b. Thermoelectric (TE) modules harvest the thermal gradient created by sunlight heating one textile layer.

c. Compatible in outdoor or wearable scenarios where sunlight induces a temperature difference across layers.

Piezoelectric/Triboelectric + PV/TE

i. Mechanical and environmental (solar/thermal) sources complement each other.

ii. Hybrid integration in textiles allows near-continuous energy generation under varied stimuli.

iii. E.g., PV active in daylight; piezo/tribo active during user movement; TE usable with body–ambient temperature differences (Table 2).

Table 2 Combined vs. Individual performance

Mode	Individual Power Density	Hybrid Power Synergy	Efficiency Boost
Piezoelectric	μW–mW/m²	Adds mechanical output	Depends on motion frequency
Triboelectric	μW–mW (lab: W/m²)	Enhanced with multiple contact points	High peak, variable
Photovoltaic	mW–tens mW/m²	Continuous under light	Efficient under direct sunlight
Thermoelectric	μW–mW/m²	Boosted by sunlight or body heat	Modest in wearables

Synergy Gains: Combined systems don't merely add outputs—they improve reliability. For example, a hybrid PV-TE-piezo structure can yield >2x total output compared to each source alone under real-life wear conditions.[13]

Design considerations

A. Multilayered structures or yarn-coaxial layouts for spatial separation. o Smart interconnects to manage varied AC/DC and voltage levels.

B. Flexible, breathable substrates needed to retain textile comfort.

Practical integration examples

A. 2D materials (e.g., MXenes, graphene) facilitate hybridization due to flexibility, conductivity, and compatibility across PV, TE, and triboelectric applications[14]

B. Smart garments combining PV (chest/back), TE (spine/waist), and triboelectric patches (elbows/knees) can power low-power IoT devices.

Conclusion

Yes, hybrid energy harvesting in textiles is both feasible and functionally superior to single-method approaches. Combining piezoelectric, triboelectric, photovoltaic, and thermoelectric systems enables complementary power sourcing—mechanical, thermal, and solar—resulting in higher overall efficiency and reliability. Hybrid systems outperform individual techniques, especially in dynamic, real-world wearable applications.

Textile energy harvesting techniques—based on piezoelectric, thermoelectric, photovoltaic, and triboelectric principles—are technically feasible but still face several scalability challenges before widespread commercial deployment. These span material constraints, fabrication processes, integration issues, and economic viability.

Scalability challenges by technology

Piezoelectric textiles

a. Material Processing: Piezoelectric ceramics (like PZT) require high-temperature sintering, incompatible with textile substrates. Polymer alternatives (e.g., PVDF-TrFE) are more scalable but have lower energy conversion.

b. Fiber Integration: Aligning dipoles in yarns via poling at industrial scale is difficult. Electrically wiring each fiber for output collection increases manufacturing complexity.

c. Output Limitations: Energy harvested per unit area remains low (μW–mW/m²), requiring large surfaces for practical output.

Thermoelectric textiles

A. Efficiency Issues: Organic thermoelectric materials offer flexibility but low efficiency. High-performing inorganic materials are rigid and not textile-friendly.

B. Material Availability: Limited n-type polymers and thermoelectric inks restrict formulation choices.

C. Gradient Dependence: Requires sustained temperature differences, hard to guarantee across body-worn garments in varying environments.

Citation: Parachuru R, Ganti VA. Energy harvesting textiles – a look at selected textile-based energy harvesting approaches of the last decade. *J Textile Eng Fashion Technol.* 2025;11(4):194–200. DOI: 10.15406/jteft.2025.11.00422

Photovoltaic textiles

i. Environmental Instability: Perovskite and dye-sensitized cells are moisture/UV-sensitive, needing complex encapsulation.

ii. Fabrication Complexity: Techniques like sputtering or inkjet printing must be adapted to rough, porous fabric surfaces.

iii. Cost: High costs of deposition processes and PV materials limit commercial competitiveness compared to traditional PV panels.

Triboelectric textiles

a) Surface Durability: Repeated washing, rubbing, and sweat can degrade triboelectric surfaces, affecting charge generation.

b) Electrical Management: Requires rectifiers and energy storage for practical use, adding complexity.

Integration at Scale: Ensuring uniform contact/separation mechanisms in large fabric panels remains technically demanding (Table 3).

Table 3 General challenges across all techniques

Challenge	Description
Textile Compatibility	Functional coatings must withstand bending, washing, and abrasion. Most energy harvesting materials are not inherently textile-grade.
Manufacturing Scale	Lab-scale printing, coating, or knitting doesn't always translate to roll-to-roll or garment-level production.
Power Density	Even in combined systems, output per area may not yet support high-demand electronics.
Cost & Standardization	Lack of cost-effective production processes and standardized testing impedes commercialization.

Noteworthy Insights

i. According to Torah et al.,[15] functional materials must meet textile constraints: <150°C processing temperature, flexibility, and wash resistance[15]

ii. Dolez (2021) highlights the lack of fully integrated systems combining comfort, energy harvesting, and electrical reliability at wearable scale.[16]

iii. 2023 review chapter emphasizes that different fabrication methods (e.g., embroidery, screen-printing, fiber spinning) influence scalability based on end-use applications and targeted energy mechanisms.

Conclusion

While textile-based energy harvesting is technically achievable, true commercial scalability is constrained by material limitations, fabrication complexity, and cost-performance trade-offs. Piezoelectric and triboelectric systems are closer to scale via fiber/yarn integration, whereas photovoltaic and thermoelectric options require breakthroughs in stability and manufacturing. Collaborative innovation in materials science, textile engineering, and device design is essential to bridge the lab-to-market gap.

Comparison of energy performance between hybrid smart textiles and commercia batteries

Hybrid smart textiles integrate multiple energy harvesting mechanisms (solar, mechanical, thermal) and occasionally energy storage, offering self-sustained power for low-power wearable electronics. But how do they compare to conventional commercial batteries in terms of energy performance? (Table 4)

Table 4 Performance metrics comparison

Feature	Hybrid Smart Textiles	Commercial Batteries
Energy Density	Typically, μWh–mWh/cm²	100–250 Wh/kg (Li-ion)
Power Density	μW–mW/cm²; peaks at ~W/m² (triboelectric+solar)	100–1000 W/kg
Sustainability	Self-replenishing (ambient energy)	Finite charge cycles; requires replacement
Scalability	Emerging for wearables	
Flexibility & Comfort	High (especially with nanofibers and textile weaving)	Mature and mass-produced Low (rigid form factors)

Key findings from literature

1) Micro-Cable Hybrid Textile

a. Design: Combines solar fiber cables and triboelectric yarns.

b. Performance: A 4×5 cm² patch charged a 2-mF capacitor to 2 V in 1 minute under sunlight and motion, enough to power watches and charge phones briefly.[17]

2) All-Textile Energy Storage

a. Configuration: Zinc-ion battery + supercapacitors in parallel.

b. Output: 95.1 μWh capacity at 1 mA/cm² between 1.9 V–0.9 V—adequate for e-textile sensors but far below commercial battery capacity.[18]

3) Application Domain

Smart textiles are ideal for low-power electronics like wearables, environmental sensors, or health monitors—not high-drain devices like laptops or electric vehicles

Conclusion

Hybrid smart textiles currently cannot match commercial batteries in terms of energy or power density. However, they provide sustainable, self-powered operation without recharging, which is ideal for lightweight, flexible, and wearable applications. Their strength lies in complementing traditional batteries or replacing them in low-demand, mobile, or maintenance-free environments.

Can energy harvesting textiles be made washable -- key strategies for washability

To ensure energy harvesting textiles are washable, researchers are designing systems that combine durable encapsulation, resilient materials, and wash-compatible architectures. These strategies aim to

preserve functionality under mechanical stress, water exposure, and detergent exposure—key for user acceptance and product longevity

Encapsulation with textile-compatible coatings

Approach: Laminating energy harvesting modules with waterproof, flexible synthetic textiles using industrial lamination (e.g., PU films, silicone rubber).

Example: Embedded monocrystalline silicon solar cells endured up to 50 laundry cycles (ISO 6330:2012) while retaining full energy performance in most samples.

Yarn-integrated electronics

Approach: Embedding miniature solar cells within the yarn's core and sealing them with fine copper wires and textile fibers.

Performance: Maintained 90% power after 15 machine washes and retained fabric softness, breathability, and flexibility.[19]

Electrospun nanofiber coatings

Approach: Coating conductive yarns with electrospun PVDF or polyamide nanofibers enhances adhesion and durability.

Example: PVDF-coated CNT yarns retained functionality after 10 washing cycles and 1,200 rubbing cycles, with increased power after fatigue cycles.[20]

Self-charging all-in-one systems

Approach: Combine washable triboelectric nanogenerators (TENGs) and supercapacitors in single flexible units using carbon cloth coated with waterproof silicone rubber. Performance: Maintains voltage output (~280 V) after multiple use cycles and is suitable for direct garment integration (Table 5).[21]

Table 5 Summary of techniques

Method	Wash Durability	Key Features
Textile encapsulation (lamination)	50 cycles	Maintains photovoltaic efficiency
Yarn-embedded cells	15 cycles	Retains fabric flexibility
Electrospun coatings	10+ cycles	Adheres well to fibers; abrasion-resistant
TENG + supercapacitor systems	Confirmed in simulation	Self-charging, stretchable, waterproof

Conclusion

Washability in energy harvesting textiles is achievable through material engineering (PVDF, silicone, carbon cloth) and smart integration (yarn-embedded electronics, nanofiber coatings, laminated structures). The best-performing systems maintain over 80–90% efficiency after multiple domestic wash cycles, meeting textile industry standards and paving the way for commercial applications.

Recommendations for improving commercial viability and real world usability of energy harvesting textiles

To improve the commercial viability and real-world usability of energy harvesting textiles, future efforts should prioritize the development of multifunctional, textile-compatible materials that combine flexibility, durability, and high energy conversion efficiency. Standardizing washable encapsulation methods such as breathable hydrophobic coatings or nanofiber barriers will be essential to ensure long-term performance in everyday environments. Roll-to-roll fabrication techniques and coaxial yarn architectures must be scaled to reduce manufacturing costs and enhance reproducibility. Integration of modular energy storage (e.g., flexible supercapacitors or textile batteries) and power management circuits within the garment architecture can enable self-sustaining systems. Additionally, establishing industry-wide testing protocols for mechanical fatigue, laundering, and skin-contact safety will accelerate consumer trust and adoption in sectors such as healthcare, sportswear, and military gear.

Acknowledgments

None.

Funding

None.

Conflicts of interest

The authors declare that there is no conflict of interest.

References

1. Satharasinghe A, Hughes-Riley T, Dias T. A review of solar energy harvesting electronic textiles. *Sensors*. 2020;20(20):5938.
2. Iftikhar Ali M, Islam MR, Yin J, et al. Advances in smart photovoltaic textiles. *ACS Nano*. 2024;18(5):3871–3915.
3. Yang F, Peng P, Yan ZY, et al. Vertical iontronic energy storage based on osmotic effects and electrode redox reactions. *Nat Energy*. 2024;9:263–271.
4. Batra R, Pourjafarian N, Chang S, et al. Fabricating wearable textile-based triboelectric nanogenerators. *Computer Science - Human-Computer Interaction*. March 2025.
5. Hossain IZ, Khan A, Hossain G. A piezoelectric smart textile for energy harvesting and wearable self-powered sensors. *Energies*. 2022;15(15):5541.
6. MIT, Federal University of Ceará. Dual Envelope Multifunctional Fabric, an ongoing research project on PE-based fabric harvesting both mechanical and thermal energy for Navy applications. Brazil.
7. Avares J, Lacik J, Pinho P, et al. Advancing sustainable RF energy harvesting for wearable electronics with 2.45 GHz textile-printed rectennas. *Sci Rep*. 2025;15:24429.
8. Dolez P. Energy harvesting materials and structures for smart textile applications: Recent progress and path forward. *Sensors*. 2021;21(18):6297.
9. Ansell GB, Modrick MA, Longo JM, et al. Calcium manganese oxide Ca2Mn3O8. *Acta Crystallogr B*. 1982;38(6):1795–1797.
10. Verduci R, Romano V, et al. Solar energy in space applications: Review and technology perspectives. *Adv Energy Mater*. 2022.
11. Satharasinghe A, Hughes-Riley T, Dias T. A review of solar energy harvesting electronic textiles. *Sensors*. 2020;20(20):5938.
12. Avloni J, Florio L, Henn AR, et al. Thermal electric effects and heat generation in polypyrrole coated PET fabrics. *Materials Science*. 2007.
13. Dolez P. Energy harvesting materials and structures for smart textile applications: Recent progress and path forward. *Sensors*. 2021;21(18):6297.
14. Ali I, Dulal M, Karim N, et al. 2D material-based wearable energy harvesting textiles: a review. *Small Structures*. 2023;5.
15. Torah R, Lawrie-Ashton J, Li Y, et al. Energy-harvesting materials for smart fabrics and textiles. *MRS Bulletin*. 2018;43(3):214–219.

Copyright: ©2025 Parachuru et al.

16. Dolez P. Energy harvesting materials and structures for smart textile applications: Recent progress and path forward. *Sensors*. 2021;21(18):6297.

17. Chen J, Huang Y, Zhang N, et al. Micro-cable structured textile for simultaneously harvesting solar and mechanical energy. *Nat Energy*. 2016;1(10):16138.

18. Yong S, Hillier N, Beeby S. Enhanced textile hybrid energy storage device. *2022 PowerMEMS*. 2022:208–210.

19. Satharasinghe A, Hughes-Riley T, Dias T. An investigation of a wash-durable solar energy harvesting textile. *Prog Photovoltaics*. 2020;28(6):578–592.

20. Busolo T, Szewczyk PK, Nair M, et al. Triboelectric yarns with electrospun functional polymer coatings for highly durable and washable smart textile applications. *ACS Appl Mater Interfaces*. 2021;13(14):16876–16886.

21. Huang Y, Wang L, Li X, et al. Washable all-in-one self-charging power unit based on a triboelectric nanogenerator and supercapacitor for smart textiles. *Langmuir*. 2023.

Citation: Parachuru R, Ganti VA. Energy harvesting textiles – a look at selected textile-based energy harvesting approaches of the last decade. *J Textile Eng Fashion Technol.* 2025;11(4):194–200. DOI: 10.15406/jteft.2025.11.00422