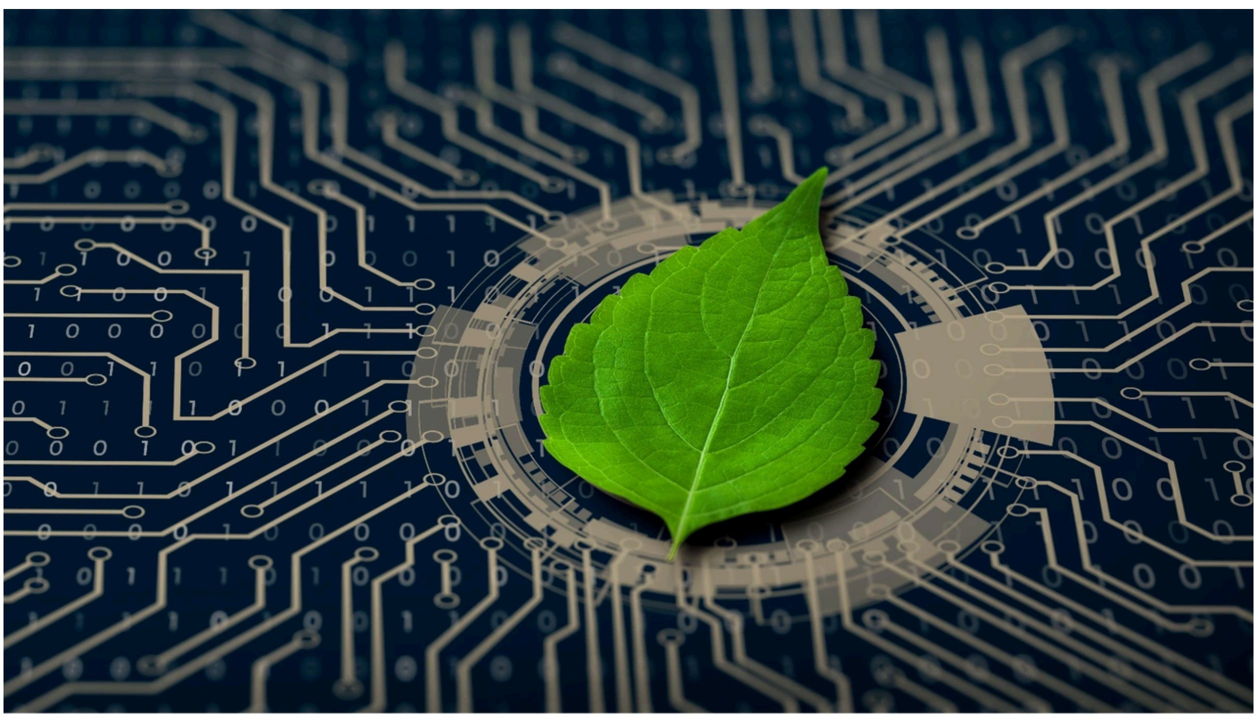
# Building Sustainable Circuits: Eco-Friendly Design For Consumer Electronics

***With 25+ years in embedded systems and electrical design, Dhananjay Patil explains how engineers are rethinking circuit design to reduce e-waste and power a more sustainable electronics future.***

**By Michael Martin**
**April 9, 2025**



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Many large corporations have declared carbon-neutral goals, but attaining those goals relies on implementation and innovative design. From an electrical circuit design perspective, sustainability in consumer electronics involves incorporating energy-efficient components, minimizing power consumption, and optimizing circuits to reduce environmental impact throughout the device's life cycle. One promising advancement in this space is ambient energy harvesting in consumer electronics hardware design. This technology enables capacitors to store harvested energy from ambient or solar light. This approach can potentially prevent billions of batteries from ending up in landfills, thus protecting the environment.

Professionals like Dhananjay Patil are the unsung heroes making the magic behind the curtain of daily technology to achieve a more sustainable future and reach for the vision of biodegradable green computing. Patil has over 25 years of experience in embedded systems, electrical design engineering, and product development. His knowledge in the hardware and power management domain, from prototype to mass production and from milliwatt to megawatt power management design, offers a unique perspective on the state of sustainable embedded systems today and how the industry continues to evolve.

## Q: How does design thinking help achieve sustainable circuit designs?

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**Patil**: The trend is to reduce total power consumption and use more sustainable materials. Multifunctional integrated circuits (ICs) decrease the overall component count by sharing hardware resources for multiple functions. This decreases power consumption, reduces thermal demands, and minimizes printed circuit board (PCB) space. As a result, circuit design is more compact and sustainable and aligned with design for disassembly (DfD) principles.

These new-generation ICs require less reliance on traditional power through energy harvesting and hybrid supercapacitors, thereby reducing the need for batteries and maintenance. Passive energy harvesting technology has progressed beyond direct solar light photovoltaic cells (PV cells) to ambient light PV cells that can capture energy from as little as 150 lux, about the brightness of a restroom or waiting area. Integrating these PVs into prototyping and simulation helps designers and engineers test and analyze designs before they go to production, ensuring energy-efficient, lower-footprint products. In aggregate, this decreases the need for billions of batteries, leading to a massive reduction of e-waste in the consumer electronics sector.

## Q: What tools have changed circuit design, and how are engineers using these tools to address technical challenges today?

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**Patil**: The most significant change is the depth of detail that industry simulation software solutions now offer for material modeling, thermal, and power management simulation. Dynamic voltage frequency scaling (DVFS) is a technique where controllers adjust power consumption based on real-time demand, improving power efficiency. Power loss can also be optimized using tools like Allegro sigrity, Hyperlinx, PI, or Keysight ADS, while product thermal behavior is simulated through mechanical computer-aided design (CAD) tools like SolidWorks, Ansys, or Autodesk.

Engineering teams can optimize power delivery by fully modeling materials and simulating thermal demands while reducing component size. This leads to longer-lasting materials, as lower energy demands generate less thermal stress, ultimately resulting in more efficient and durable internet of things (IoT) products.

The ability to model and simulate different materials has enabled rapid prototyping of green chemistry material solutions, like recyclable composite materials. Emerging materials such as conductive inks, organic semiconductors, and advanced alloys are making their way to production and helping to realize a sustainable future. Optimizing PCB use and using RoHS-compliant, hazard-free materials further result in lower-footprint products and a future of sustainable circuits. This advancement fosters the development and early gains in green computing, a horizon to keep an eye on as sustainable computing evolves.

The success of circuit design sustainability can be measured using key metrics such as power efficiency, material sustainability, design longevity, and recyclability. Power efficiency is evaluated through power consumption, standby power, and thermal dissipation, ensuring minimal energy waste. Material sustainability and recyclability are assessed using RoHS compliance, the percentage of recyclable components, and ease of disassembly, with the overall goal of reducing environmental impact. Finally, design longevity is measured by modularity and firmware upgradability, ensuring products last longer and generate less e-waste. These metrics help track and guide engineering team efforts to make measured improvements, collectively enabling the industry to meet sustainability goals.

## Q: What are some of the social and system challenges consumer electronics face, and how are those challenges being addressed?

When considering carbon-neutral goals, it is crucial to consider offsetting entire supply chain footprints and closed loop recycling as more comprehensive sustainability goals. Supplier data on product and network sustainability metrics is becoming increasingly important for contract considerations, including for multi-regional compliance and regulations of intellectual property (IP) and industry and regionally specific energy standards (such as IEEE 802, ISO 50001 or the global regulation IEC 62301). As the IP and international legal responses to technology development progress, there will be emerging considerations for partnerships of artificial intelligence (AI) integration to system-on-chip (SoC) developments, as seen with the 2024 partnership of Intel and Cadence. With the increasing embeddedness of IoT systems and consumer electronics, the network scope is essential in the product life cycle assessment (LCA) to realize sustainable computing and circular economy goals.

## Q: What are some real-world examples of organizations that have effectively designed and developed sustainable consumer electronics?

**Patil**: Companies like Fairphone and Apple have led the way in sustainable electronics. Apple has reduced carbon emissions by using recycled aluminum and renewable energy in production and targets its supply chain to achieve carbon-neutral goals by 2030. Similarly, Sony is currently developing ultra-low power microcontroller chipsets for IoT devices. Collectively, these organizations create the conditions engineering teams need to drive the industry toward a circular economy where innovation means low-power, carbon-neutral, or even carbon-negative biodegradable computing.

## The Future of Sustainable Circuit Design Is Collaboration

With electrical circuits designed to reduce standby power consumption, optimized system power management, and carefully planned material selection in PCB layouts, overall energy consumption and electrical material waste are being reduced. As large companies adopt and pursue sustainability goals, the market pressure for the production and tracking of sustainable circuits continues to drive innovation. Sustainability in circuit design is not solely dependent on technical advancements and sound design; it requires collaboration across engineering teams, supply chains, and manufacturing ecosystems.

The success of sustainable hardware lies in the effective implementation of these circuit optimizations as solutions to real-world problems. The electronics industry can drive a circular economy by continuously refining circuit architectures and integrating sustainable design principles, boosting performance while ensuring every circuit supports a cleaner planet. Through responsible engineering and forward-thinking design, technology and sustainability can thrive together.

## About the Author

*Michael Martin is a freelance writer covering technology, science, humanities, and law. He seeks to promote cross-cultural understanding and learning through written discourse on critical and emerging technologies. Michael holds a bachelor's degree in IT management from Trident University and a master's degree in technical communication and localization from the University of Strasbourg. Connect with him on LinkedIn.*

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