



## OPPORTUNITY

35

SCOPE TRANSITIONAL

## UNCERTAINTIES

Technology, Systems

## MEGATRENDS

Materials revolution

## TRENDS

Advanced computing  
Advanced connectivity  
Edge computing  
Internet of Things (IoT)  
New materials

## SECTORS IMPACTED

Agriculture & Food  
Automotive, Aerospace & Aviation  
Chemicals & Petrochemicals  
Communication Technologies & Systems  
Consumer Goods, Services & Retail  
Cyber & Information Security  
Data Science, AI & Machine Learning  
Digital Goods & Services  
Education  
Energy, Oil, Gas & Renewables  
Financial Services & Investment  
Government Services  
Health & Healthcare  
Immersive Technologies  
Infrastructure & Construction  
Insurance & Reinsurance  
Logistics, Shipping & Freight  
Manufacturing  
Materials & Biotechnology  
Art, Media & Entertainment  
Metals & Mining  
Professional Services  
Real Estate  
Sports  
Travel & Tourism  
Utilities

What if new materials enabled internet of things (IoT) devices to run indefinitely?

# LIMITLESS CONNECTION

Triboelectric nanogenerators (TENGs) enable an interconnected IoT across rural and urban contexts, powering digital twins, optimising policies without external power needs, and advancing the IoT towards energy autonomy.





## WHY IT MATTERS TODAY

The IoT can make the unknown known through real-time data.<sup>719</sup> Valuable insights are extracted through a network of physical ‘things’ embedded with sensors, software, and other technologies to capture and exchange data.<sup>720</sup> Various IoT applications, such as smartphones, intelligent monitoring, home security systems, and wearable electronic devices, already facilitate aspects of human life.<sup>721</sup>

As advanced machine intelligence and connectivity continue to grow, the global IoT market is projected to grow to just over \$12.6 trillion by 2025,<sup>722</sup> and spending on IoT ecosystems will exceed \$1 trillion in 2026,<sup>723</sup> including, for example, 62% in manufacturing, retail, professional services, and utilities.<sup>724</sup> The number of IoT devices is expected to grow from 14.6 billion in 2021 to 30.2 billion in 2027.<sup>725</sup> However, wide implementation of the IoT calls for decentralised power supplies and wireless transmission technologies at scale<sup>726</sup> along with innovative ways of reducing network traffic and managing changing types of data.<sup>727</sup> The amount of unstructured data is expected to continue to grow by 20% every year to 144ZB in 2025<sup>728</sup> and 660ZB in 2030.<sup>729</sup>

Over the past decade, TENG development has progressed rapidly, covering a wide spectrum of voltage outputs that can be applied across devices.<sup>730</sup> Combining the effects of contact electrification and electrostatic induction, TENGs effectively convert mechanical energy from the living environment or materials – polymers, metals, and inorganic materials<sup>731</sup> – into electric power or signals.<sup>732</sup> TENG development is interdisciplinary, integrating materials science, chemistry, physics, electrical engineering, medicine, and more. Future TENG developments promise to push the IoT towards energy autonomy.<sup>733</sup>

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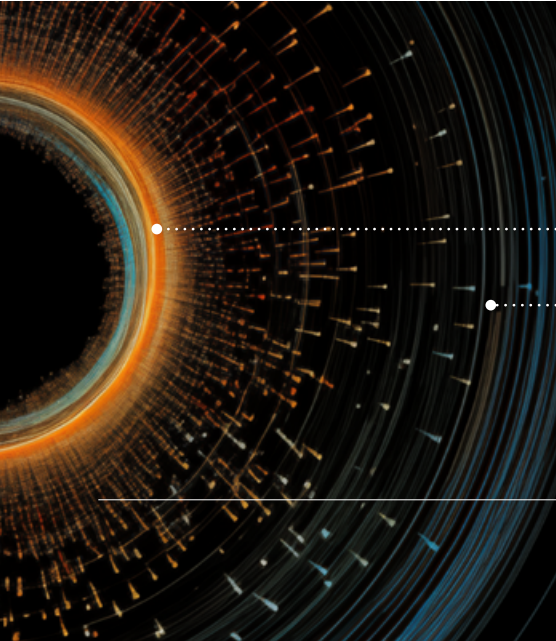
Devices powered by TENGs become part of an infinitely connected IoT capturing information from devices in vehicles, homes, telecommunication systems, and nature throughout rural areas, cities, and countries. With advanced machine intelligence, data from TENGs are used to power up digital twins and optimise policy and innovation outcomes without the need for an external power supply such as batteries or dependency on intermittent sources of power such as the wind and the sun.<sup>734</sup>

## BENEFITS

Creative application of the IoT optimises efficiency and ushers in a new era of growth and well-being. Smart cities use the IoT to maximise environmental sustainability and efforts in environmental resilience and adaptation, and, as TENGs reveal detailed insights into supply chains, transportation, health monitoring, and weather patterns, among other areas, with advanced machine learning they also optimise goods and services delivery and offer innovative solutions to challenges.

## RISKS

IoT applications expand at a pace that cybersecurity is unable to keep up with, creating new data and infrastructure security vulnerabilities. IoT networks, storage, and connectivity cannot handle high-velocity, big, and multidimensional data.



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Systems Optimised

Limitless connection

