NICER PROGRAMME & INNOVATE UK CIRCULAR ECONOMY FOR SMEs

Lightricity Ltd

UKRI Interdisciplinary Centre for Technology Metals

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Towards perpetual sensors: improved sustainability of battery-less IoT devices and photovoltaic power sub-systems through implementation of circular economy compatible designs and business models

The Challenge: What we were trying to achieve

The Internet of Things (IoT) represents a rapidly growing range of applications, as products and services increase in connectivity, enabling data collection and analysis, with revenue from this sector expected to triple between 2023 and 2033[1].

The IoT has the potential to act as a circular economy (CE) enabler, both by increasing efficiencies and through tools such as in-use diagnostics which can extend product life via strategies such as proactive repair and maintenance. However, such products create significant sustainability challenges as their widespread deployment often relies on battery power, leading to concerns regarding growing amounts of battery waste and the cost and carbon footprint of battery replacements. These factors limit the scalability and sustainability of IoT systems, hindering the realization of their full potential.

At Lightricity, we already offer a more sustainable alternative to battery-powered IoT devices. Our patented indoor photovoltaic (PV) technology and power management architecture enables battery-free operation by harvesting energy from indoor lighting. However, we would like to take this a step further, integrating CE strategies and solutions into our business. Yet we face a range of challenges in our transition to a CE model. These include:

- **Technical Challenges:** balancing modular design with cost and practicality, miniaturizing devices without compromising on quality, extending device longevity through novel deep-sleep and shut-down processes which minimise stress and device degradation.
- **Financial Challenges:** There is a need to balance cost reductions with circularity as costs cannot be easily passed on to customers (i.e. reducing the cost of asset tracking systems whilst applying CE principles).
- **Market-Related Challenges:** customer buy-in for CE models is a necessity, new designs need to be compatible with existing infrastructure and integrator companies, raising awareness of sustainable solutions across the IoT industry.

Through this project we explore a range of CE strategies designed to further optimise the sustainability of our PV-powered IoT devices, including modular design, miniaturisation, design for longevity and CE business models such as servitisation.

The Barriers: What are the common barriers and how can these be overcome

Common barriers to a CE transition are wide-ranging, including financial barriers, technical barriers, market barriers and regulatory barriers. However, these are not insurmountable:

- **Grants** focussed on sustainable innovation and collaborations with universities and research organisations can help SMEs to invest in CE initiatives and take advantage of research and development opportunities to tackle increased design complexity.
- **Collaboration** and **shared infrastructure** can reduce high up-front costs. Likewise, focussing on high-impact areas first can make transitions more manageable.
- **Open-source resources** and industry best practices can provide access to specialised expertise needed to tackle CE design challenges.
- **Marketing and communication** strategies focussed on the cost and improved performance of new CE solutions and products can drive sales, providing further justification for CE investments.
- Helping to shape **CE policy** through engagement with industry associations and policymakers and participation in pilot projects can help create a clear, supportive legislative landscape which works for businesses.

[1] Vailshary, L. S. Statista. 2024. Internet of Things Total Annual Revenue Worldwide from 2020 – 2033. Available at: Worldwide IoT revenue 2033 | Statista

The Approach: How we tackled the challenge

We decided to take a dual focus, exploring both technical innovations and new CE business models.

Technical Innovations:

- **Modular design:** a key decision was to design the IoT devices with removable, reusable modular subsystems. This approach makes it easier to recycle, repair, and upgrade the devices, extending their lifespan and reducing waste.
- **Design for longevity:** we also focused on improving device longevity by minimising component stresses and the resulting material degradation. We achieved this through innovative deep-sleep and shut-down architectures for the microcontroller and wireless electronics, thus extending the life of individual components.
- **Materials Reduction:** we reduced plastic inputs by miniaturizing devices to use less casing material and investigating alternative casing materials, such as biodegradable and recycled plastics, and even exploring designs that might eliminate the need for a casing altogether. We reduced metal inputs through miniaturization (reducing requirements for tin solder and resulting in smaller PV cells and components) and by carefully considering the full lifecycle impact of component and metal sourcing.

Circular Economy Business Models:

CE business models which enabled strategies such as reuse, repair, and recycling were explored. One option considered was shifting from a device sales model to a service provision model, enabling us to retain ownership of devices, making it easier to manage their end-of-life.

Two collaborations were key to our success in this project. We worked closely with Oxford Product Design (OPD) who were tasked with supporting the design of modular subsystems and providing input on device packaging. We also worked with the UKRI Interdisciplinary Centre for Technology Metals (Met4Tech), who shared their expertise on material selection, optimizing metal usage and CE business models.

Unexpected outcomes: What we learned along the way

A potential market opportunity was identified during the project that was not anticipated at the beginning - tool asset tracking. This emerged during discussions with one of the largest UK tool and equipment hire companies. This company, a provider of tools and equipment for various customers, has a significant number of assets, highlighting a substantial market need for tracking solutions to identify significantly over- or under-utilised assets and minimise asset loss.

This market opportunity influenced the project's overall direction and outcome by:

1. **Validating market requirements:** Conversations with potential customers, including the tool hire company, reinforced the need for sustainable and cost-effective IoT solutions.
2. **Expanding the potential market:** The identification of tool asset tracking as a viable market significantly broadened the project's potential impact and commercial opportunities.
3. **Influencing future commercialisation strategies:** The project's exploitation plan was adjusted to incorporate this new market.

Key Learning: What we would do differently next time

Through our experience on this project, we learned a number of key insights which will shape future projects and efforts to embed CE thinking into our operations.

1. **Collaboration Enhances Expertise and Value:** we leveraged the expertise of various partners and subcontractors, accessing specialised expertise and capabilities.
2. **Sustainability as a Competitive Advantage:** we position our sustainable and battery-free IoT devices as a key differentiator in the market. This strategy resonates with the growing demand for environmentally friendly solutions and attracts customers seeking to reduce their environmental footprint.

3. **Circular Economy Principles Drive Innovation:** The project's commitment to circular economy principles, including design for reuse, repair, and recycling, led to significant innovations in product design, material selection, and business models. This approach pushed the boundaries of product lifecycles, demonstrating how circularity can be a catalyst for innovation.
4. **Cost Reduction for Mass Market Adoption:** reaching a sufficiently low cost is a critical barrier to penetrating high-volume markets. This cost constraint influenced design choices and decisions related to material selection and manufacturing processes.
5. **Delivering Adequate Power and Functionality:** Ensuring the devices deliver sufficient power and functionality across diverse illumination conditions is another challenge. Our PV technology is designed to operate efficiently in low-light environments, but variations in lighting levels can still impact performance. Addressing this challenge involved careful optimisation of the power management system and design considerations to maximise energy harvesting efficiency.

The Outcome: What we achieved and how it has impacted the business, society and key stakeholders

Through the project we have seen positive outcomes for the business, including enhanced product sustainability through the incorporation of CE principles in the design and manufacturing stages. Our resulting product offers a unique selling point in providing a battery-free solution in a market driven by battery powered products. As a result, we offer a means to overcome the growing battery waste generation challenge in this industry sector. We expect this distinctive aspect to set us apart from the competition and to drive sales and increased market share.

The project also led to the generation of new intellectual property, with plans for additional patent filings relating to power module innovations and architectures designed to support modularity.

Looking forward: Next steps and future directions

At Lightricity, we intend to implement our novel CE adaptations in our products, conduct customer trials, secure necessary certifications, and transition from prototype to volume production.

The project has also led to new opportunities and directions for research and collaboration, as we continue to develop the themes of modular design, design for longevity, new business models such as servitisation and new collaborations with customers and systems' integrators. Such collaborations enable the validation of design choices, feedback on real-world performance and integration of our technology into broader IoT systems and solutions.

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