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CSIRO submission to consultation on Opportunities in the circular economy

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Contents

Executive Summary

CSIRO welcomes the opportunity to provide input into the Productivity Commission's Opportunities in the Circular Economy Inquiry. As Australia's national science agency, we play a trusted advisor role to community, industry and government by undertaking research in the circular economy domain. CSIRO has actively engaged with the Productivity Commission to support this, holding two meetings with the Inquiry Team (August and September, 2024) to present the methodology behind the recent *Australia's Comparative and Competitive Advantages in transitioning to a circular economy* report (Schandl et al., 2024) delivered to the Australian Office of the Chief Scientist. These discussions covered the barriers and opportunities related to resource efficiency and the circular economy, highlighting potential economic and policy benefits for Australia. To further inform this inquiry, CSIRO highlights four key supporting research capabilities and future directions for the circular economy. In summary, these include:

Key Area 1: Measuring and Modelling Australia's Circular Economy Potential

CSIRO's metrics and modelling frameworks to assess the economic and environmental impacts of circular economy initiatives explore how improved resource efficiency can boost GDP, reduce waste, and contribute to Australia's net-zero emissions goals by enhancing material productivity and reducing the material footprint.

Key Area 2: Opportunities for Resource Recovery and Circularity in Key Circular Economy Sectors
CSIRO identifies waste streams and resource recovery opportunities, such as recycling tyres and conveyor belts, and plastics which can reduce environmental harm while fostering innovation and creating local jobs. Investments in recycling technologies and infrastructure, particularly in the mining and manufacturing sectors, could help close the material loop.

Key Area 3: Adopting International Best Practices to Overcome Barriers for Australia's Circular Economy Effort
Drawing on insights from international frameworks, such as the EU Circular Economy Action Plan and Japan's Sound Material-Cycle Society, CSIRO has proposed policy adaptations for Australia, including extended producer responsibility, right-to-repair, and harmonised recycling standards. This international alignment can help Australia overcome regulatory fragmentation and drive innovation in sustainable packaging and waste management.

Key Area 4: Place-Based Solutions for Circular Economy Innovation
Tailoring circular economy strategies to address regional needs is important due to Australia's diverse geographic and economic structure. Place-based solutions involving collaborative efforts between government, industry, and communities can help boost local resource recovery, enhance circular business models, and build resilient, sustainable economies across urban, regional, and remote areas.

These key areas provide evidence-based insights and scalable solutions that align with global best practices and local conditions. CSIRO aims to inform this inquiry to ensure that Australia can realise the full economic, environmental, and social benefits of the circular economy transition.

CSIRO response

1.1 Measuring and Modelling Australia's Circular Economy Potential

There is broad international consensus on circular economy metrics, which builds on the standards for material flow accounting outlined in the System of Environmental-Economic Accounting (SEEA) framework. This framework integrates complementary accounts for material and waste flows, as well as economic activities (UNECE[1] and OECD[2], 2024). To support Australia's circular economy potential, CSIRO's research and modelling analyses are examining circularity rates, economic impacts, and place-based opportunities.

CSIRO's Australian Material Flows Analysis to Progress to a Circular Economy report (Miatto et al., 2024a) identifies indicators including the national circularity rate, material footprint, and material productivity, complementing existing metrics such as the recycling rate and waste-to-landfill ratio. Several of the proposed indicators identified by this CSIRO report are now incorporated into the Treasury's Measuring What Matters Framework.

A key structural challenge identified within this report is that Australia's extractive, export-oriented economy limits what can be achieved through circular economy strategies, even with advanced waste management and resource recovery efforts. This underscores the importance of developing metrics that account for Australia's unique economic context, particularly to ensure fair comparisons with other nations that benefit from Australia's primary materials. It also emphasises the need to build domestic capacity to manufacture components and consumer goods across key sectors to enhance circularity and economic resilience. This report was delivered to the Department of Climate Change, Energy, the Environment and Water (DCCEEW).

CSIRO's Modelling Circular Economy Transition Targets report (Miatto et al., 2024b) includes scenario modelling based on the *UNEP[3] Global Resources Outlook 2024* (UNEP, 2024) to explore Australia's potential to improve circularity rates, reduce the material footprint, and enhance material productivity. The report also assessed the economic impacts of circular economy policies, including potential GDP growth and contributions to Australia's greenhouse gas reduction efforts. The report indicated that with targeted policies, the circular economy could contribute $48 billion USD (2015 prices) to the Australian economy by 2050 and account for one-fifth of the country's required greenhouse gas abatement. Achieving these outcomes would involve doubling Australia's circularity rate, which is close to 4% (Miatto et al., 2024b), reducing per capita material consumption, and enhancing material productivity.

CSIRO's Global Environment and Trade Model (GTEM-C) (Hatfield-Dodds et al., 2015) is one of only two global models - along with the OECD's model (OECD, 2019) - that integrates material flows within a dynamic, multi-region, and multi-sector economic framework. Although some integrated assessment models used by the Intergovernmental Panel on Climate Change (IPCC) are beginning to incorporate material flows, they often lack the economic granularity needed to fully evaluate the economic implications of a circular economy.

[1] UNECE – United Nations Economic Commission for Europe

[2] OECD – Organisation for Economic Cooperation and Development

[3] UNEP – UN Environment Programme

Ongoing modelling challenges and opportunities: CSIRO is improving how circular economy dynamics are represented in economic models by disaggregating the waste and resource recovery sector within the model's input-output structure and developing specialised technology bundles, such as for the built environment, along with cost curves for recycling economies.

Under the National Environmental Science Program (NESP) Sustainable Communities and Waste Hub, CSIRO is developing circular economy metrics for States and Territories which include pilot methodologies for regional-level circular economy indicators.

An area that warrants further investigation in the circular economy potential is understanding employment impacts and skill requirements associated with Australia's circular economy transition, including in regional areas. Current methodologies, such as Circle Economy's Circular Jobs Methodology (Circle Economy, 2024), do not adequately capture the full potential of circular economy jobs or the training and upskilling needs for both the existing and emerging workforce.

1.2 Opportunities for Resource Recovery and Circularity in Key Circular Economy Sectors

CSIRO's research underscores how innovation and technology developments can make a change to recycling and resource recovery outcomes, and we highlight a few key examples related to recycling end-of-life tyres and conveyor belts, the recovery of offshore gas and oil infrastructure, battery recycling and advanced recycling for polymers from end-of-life plastics. In addition, we explore circularity of biomass materials within the agricultural and food sectors. Resource recovery outcomes hold potential for circularity in closed, and open loop cycling, particularly when aligning to R-framework hierarchies.

CSIRO's report on the circular economy for end-of-life tyres and conveyor belts highlights key opportunities and challenges for improving value recovery and waste management in Australia (Kaksonen, et al., 2024). The findings emphasise the importance of regulating product stewardship to hold manufacturers accountable, potentially combined with bans on landfill disposal for these materials. The report identifies the need for consistent waste classifications and tracking systems to enhance transparency and material flows. Additionally, it recommends developing recycling hubs in regional areas to support collection and processing.

The analysis reveals that energy recovery options, such as tyre-derived fuel (TDF) used in cement manufacturing, can reduce emissions by replacing coal. However, it warns against over-reliance on such solutions as they eliminate material circularity by destroying the rubber. To achieve a truly circular economy, the report recommends investing in recycling technologies, such as devulcanization, which can enable rubber reuse in new products, and establishing reverse logistics systems to streamline material recovery.

The report also notes that on-site disposal in the mining sector remains a challenge, as a significant portion of off-the-road (OTR) tyres are buried at mine sites. Addressing this issue requires a combination of contract designs for recycling services, logistical solutions, and stricter regulations. These findings are intended to inform new state and federal regulations and promote more sustainable practices across Australia's tyre and conveyor belt sectors.

CSIRO investigated the challenges, regional opportunities and social acceptability for the multi-billion dollar decommissioning of obsolete offshore oil and gas infrastructure in Australia. Through in-depth stakeholder engagement, review of international case studies and the literature, five key enablers for the sustainable development of the offshore oil and gas decommissioning industry in Australia were identified. These enablers include:

- Pathways for adaptative governance
- Enhanced planning and decision-making
- Collaboration and partnership
- Technical innovation for resource recovery
- A regionally specific social acceptability framework.

Two technical reports were generated to support the development of *Australia's Offshore Resources Decommissioning Roadmap* (Boxall et al., 2024; Walton et al., 2024). In addition to dealing with the current footprint of obsolete infrastructure, the reports outline enhanced and progressive planning and approvals that consider circular economy at the front end of new projects, including design for decommissioning, early and adaptive identification of resource recovery and secondary market pathways, reuse potential of infrastructure such as depleted reservoirs for geological storage of carbon dioxide, and improved environmental management of offshore decommissioning activities.

CSIRO analysed circular biomass opportunities for Australia. Australia's biomass cycling holds the potential for enhancing healthy and productive regions providing food, goods, and energy in a thriving, equitable economy. This is especially the case with both open- and closed- loop resource cycling based on R-framework hierarchies where ideally, there is smarter product use and manufacturing (refuse/rethink/reduce), extending the use phase (reuse/repair/repurpose), then recycling and recovering for energy.

Australia's biomass material flows and circularity rates point to specific strategic opportunities. Onshore Australia's biomass extraction is about ~400 Mt per year (2019 data) with a theoretical biomass circularity rate of 23% (Miatto et al., 2024c). This contrasts with a 63% end-of-life biomass recycling rate achieved onshore in 2019 (Miatto et al. 2024c), indicating there is potential for additional higher-order and open-loop utilisation of bio-based resources. Furthermore, the developing bioeconomy and the need for low carbon liquid fuels, including Sustainable Aviation Fuel and Renewable Diesel, is creating increased demand for bioresources and sharpening our need to increase circularity. CSIRO has pointed to the need to evaluate material flows through more in depth analyses, and has identified several opportunities for higher value use of biomass as valuable alternatives for food, animal feed, or fibre, including innovative new products and services, on-farm recovery of broad-acre and horticultural crop waste, and bioenergy and water-capture systems in agriculture chains. A full-harvest approach is key to which a "whole of animal" and "whole of crop" accelerates the circularity of resources by utilising all parts of the organism at the highest possible value (Hetherington et al., 2022). Importantly, realising industrial symbiosis opportunities in biomass cycling will be an essential element for the circular economy transition, and CSIRO is partnering to stimulate this, such as in exemplar regions like the Bega Circular Valley. Biomass opportunities at the macro scale require a coordinated systems approach to realise the aims of the bio-circular economy, bioenergy production, and net zero emissions while regenerating nature. It is important to note that trade-off analyses of the biomass utilisation options are needed, which requires robust data and unprecedented co-ordination and cooperation (Arsic et al., 2022).

Natural-fibre circularity for clothing and textiles is one of Australia's comparative advantages, including cotton, wool and the emerging hemp industries (Schandl et al., 2023). With significant pollution concerns with fossil-fuel based fibres, plant and animal fibres and their production systems continue to offer biodegradable alternatives for clothing and textile value chains. CSIRO, with its university and industry collaborators, outlined opportunities for cradle-to-cradle textile circularity, including designing out fibre pollution in the creation of textiles, extending clothing use, behaviour change in production and "consumption" of textiles, and prevention of textiles to landfill (MacMillan et al., 2022). With Australia leading the charge through Seamless, the world's first extended product stewardship scheme for clothing,

and a strong cross-sector willingness and expertise, and increasingly connected research, community, and industry sectors, Australia's textiles circularity onshore is accelerating at local, regional, and national scales.

CSIRO assessed the material demand, environmental impact, and carbon implications of Australia's building stock through 2060 using spatially explicit asset modelling (Soonsawad et al., 2022). The study examines the contribution of embodied carbon in the built environment to Australia's net-zero pathway. As Australia commits to building one million new homes to address the housing crisis, the circular economy outcomes of future developments will create a legacy. This research explores alternative urban design approaches and building material choices, including the role of prefabricated construction (PrefabAUS, 2023) in accelerating construction timelines, reducing site waste, and improving the carbon and material efficiency of new buildings.

CSIRO's reports on lithium-ion battery recycling highlight the need for advanced recycling to manage the growing volume of battery waste driven by the increased use of electric vehicles and renewable energy storage systems (King, Boxall and Bhatt, 2018; Zhao, et al., 2021). Currently, only 10% of lithium-ion batteries are recycled in Australia, with waste growing by 20% annually. The report identifies both environmental risks, such as toxic leaks and fire hazards, and economic opportunities—estimating that proper recycling could generate up to $3.1 billion for the Australian economy by recovering valuable materials like lithium, cobalt, and nickel.

The report emphasises the importance of developing domestic recycling capabilities through policy improvements, such as extended product stewardship and better battery waste transportation regulations. It also explores technical challenges, including battery discharge safety and the recovery of valuable components through innovative dry-shredding technologies. Ultimately, CSIRO aims to support the circular economy by reusing recovered materials in new batteries and reducing reliance on mining new resources, contributing to sustainable industry growth in Australia.

In addition to the identification of barriers and opportunities for battery and e-waste recycling, **CSIRO also developed innovative laboratory-scale processes for metal recovery** (Van Yken et al., 2023a; 2023b; 2024). The application of integrated, biology-based processes for resource recovery presents an economically viable and alternative pathway for metal recovery when compared to traditional metal processing methods that are energy intensive. When developing new recycling technologies, CSIRO combines innovative technology development with economics, social acceptability, and supply chain integration to provide data and evidence for the application of recycling technology at scale in Australia.

CSIRO recently produced a report on critical mineral circularity (Vernon et al.,2023). Specifically, how Australia can embrace a circular economy in critical minerals; reviewing relevant international circular economy policies and initiatives, and identifying opportunities and challenges for Australia in this space. The report findings indicate that a critical minerals circular economy for Australia will require global engagement and cooperation and support for downstream value adding processes and advanced manufacturing.

CSIRO's report on advanced plastic recycling highlights the potential of innovative technologies to address Australia's plastic waste challenges by complementing existing recycling methods (King, Hutchinson and Boxall, 2021). Advanced recycling, also referred to as chemical or molecular recycling, processes hard-to-recycle plastics—such as mixed, contaminated, or flexible plastics—into valuable products like food-grade polymers or fuels. This approach supports Australia's goals of recycling 70% of plastic packaging by 2025 and achieving an 80% resource recovery rate by 2030.

The report underscores the need for new technologies, particularly following the plastic waste export ban, to prevent waste from ending up in landfills. Advanced recycling technologies enable the conversion of waste plastics into reusable chemical building blocks through processes like depolymerisation and pyrolysis,

fostering a circular economy. The report also emphasises that Australia has the industrial infrastructure and skills to implement these technologies, which could help meet both domestic and global demand for recycled products

CSIRO's research portfolio aimed at Ending Plastic Waste aggregates research across the organisation dedicated to mitigating the environmental impact of plastic waste through the principles of a circular economy. This research agenda encompasses several key objectives around the life cycle of plastics: Firstly, through developing innovative technologies and materials aimed at optimising the production, utilisation, and recycling of plastics. This includes exploring novel polymer chemistries, advanced recycling processes (biological and non-biological), and the development of biodegradable and compostable alternatives. Secondly, we are investigating strategies to maximise resource recovery from plastic waste streams, transforming them into valuable commodities and minimising environmental externalities. This involves research into waste sorting technologies, chemical recycling, and the development of markets for recycled plastic materials with remote communities.

Furthermore, **CSIRO is committed to revolutionising packaging and waste management systems through interdisciplinary approaches**. This includes research into sustainable packaging design, optimised logistics, and the development of decision-making tools to inform policy and practice. Critically, CSIRO recognises the importance of understanding and influencing human behaviour in relation to plastic consumption and disposal. Therefore, the research portfolio also encompasses social science research aimed at identifying the drivers of plastic waste generation and developing interventions to promote sustainable practices. Through these multifaceted research endeavours and working to connect across government, industry, research and community sectors, our work aligns with the global effort to address plastic pollution.

1.3 Adopting International Best Practice to Overcome Barriers for Australia's Circular Economy Effort

Australia's efforts in waste management and resource recovery, supported by voluntary stewardship schemes, take-back programs, and initiatives like the Australian Packaging Covenant Organisation (APCO), provide a solid foundation for the circular economy transition. However, adopting international best practices such as the EU Packaging and Packaging Waste Regulation (PPWR), Extended Producer Responsibility (EPR), Right to Repair (R2R), the EU Circular Economy Action Plan (CEAP), and Japan's 4th Fundamental Plan for a Sound Material-Cycle Society (see short summaries in Appendix A) can further advance Australia's transition to a circular economy. These frameworks offer valuable insights into overcoming structural challenges and aligning economic growth with sustainability goals. These international frameworks need to be adopted for Australia's economic and policy conditions.

National Circular Packaging Strategy: Implementing a packaging framework like the new European Packaging and Packaging Waste Regulation (PPWR) can introduce mandatory recycling targets and design standards for packaging. To align with Australia's economy, the focus would need to include reusable packaging systems and clearer labelling, helping consumers improve sorting practices. State and federal coordination will be crucial for nationwide consistency, strengthening the effort of the Australian Packaging Covenant Organisation (APCO) to achieve the ambitious Australian targets.

Consideration of Extended Producer Responsibility (EPR) Schemes: Drawing on EPR models from the EU and Japan, broadening EPR schemes across multiple sectors in Australia can encourage producers to take greater responsibility for end-of-life product management. This can promote sustainable product design, reduce waste to landfill, and ease the burden on local governments for waste management. Importantly, an Australian EPR scheme would need to extend to offshore producers who supply most of Australia's consumer goods.

Right to Repair (R2R) Framework: Introducing R2R policies would empower Australian consumers and small businesses by providing access to affordable spare parts, repair manuals, and repair services, reducing e-waste. It would also stimulate local repair industries and create green jobs, particularly in regional areas.

Sustainable Product Design and Innovation: Drawing on the European Union Circular Economy Action Plan (CEAP) product lifecycle focus, Australia can set eco-design standards to make products more durable and recyclable. Supporting circular business models such as product-as-a-service can promote innovative approaches in sectors like electronics, textiles, and construction.

Integrated Circular Economy-Climate Policy: Japan's focus on linking circular economy practices with climate goals provides a model for Australia to follow. By integrating circularity into net-zero emissions strategies, Australia can leverage material efficiency to reduce greenhouse gas emissions while strengthening climate resilience. The Australian sector plans for industry, resources and the built environment are providing good examples for such integration.

Infrastructure and Regional Adaptation: Like Japan, Australia can regionalise circular economy efforts, tailoring policies to the needs of urban, rural, and remote areas. Investments in domestic recycling infrastructure will reduce reliance on exporting waste while fostering industrial symbiosis between local industries.

Circular Economy Metrics for Monitoring and Accountability: Following the EU's lead in data-driven circularity metrics, Australia can benefit from robust indicators to track material flows, waste generation, and recycling rates. Customised metrics will ensure that Australia's resource-export economy is fairly evaluated in global comparisons, recognising the value of materials provided to other nations.

Public-Private Collaboration and Skills Development: Like Japan's model, Australia will benefit from collaboration between government, businesses, and communities. Additionally, addressing skills gaps through training programs will prepare the workforce for emerging roles in circular industries.

By adopting and adapting these international best practices, Australia can enhance resource efficiency, boost economic resilience, and reduce environmental impact. A national circular economy strategy tailored to Australia's conditions, focusing on regional adaptation, climate alignment, and innovative business models, will drive sustainable economic growth while positioning Australia as a global leader in the circular economy transition.

1.4 Place-Based Solutions for Circular Economy Innovation

Australia is committed to evolving its economy to enhance living standards and reduce environmental impacts by achieving net-zero emissions and fostering a circular economy. Local councils, tasked with delivering community services at the grassroots level, face the tangible challenges and opportunities this transition presents. By fostering liveable and sustainable communities, councils can attract top talent, support thriving industries, and promote quality employment opportunities. This vision is underpinned by investments in affordable housing, public transportation, cost-effective food options, and renewable energy sources. The planning and investment decisions made by councils are crucial, yet decision-makers must navigate the complexities and uncertainties of these choices, often amid diverse and sometimes conflicting visions for the future.

Regional councils and regional communities in Australia are facing the implementation of Australia's net zero and circular economy transition, which requires profound changes in the ways in which housing, mobility, energy and food are provided, and waste management and resource recovery are organised to capture opportunities, build comparative advantage and reduce risks of the transition. CSIRO has partnerships with regional communities including the Bega Circular Valley in NSW, Shepparton in Victoria

and is exploring additional regional circular economy initiatives with Launceston in Tasmania and Toowoomba in Queensland to support place-based circular economy solutions.

Further Engagement with the Productivity Commission Inquiry

We thank the Productivity Commission for the opportunity to provide a summary of CSIRO's research capability and research outputs. We would be pleased to provide further details on the activities referenced in this submission. For more information, please contact GovernmentRelations@csiro.au.

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APPENDIX A: International Best Practices

The EU Packaging and Packaging Waste Regulation (PPWR) (EU Commission, 2024) is a comprehensive legislative framework aimed at reducing packaging waste, improving recycling, and promoting sustainable packaging solutions across the European Union. It replaces the previous Packaging and Packaging Waste Directive (PPWD) to align with the EU's Green Deal and circular economy goals. The PPWR introduces mandatory targets for reducing packaging waste, encourages reusable and recyclable packaging, and sets specific design standards to facilitate high-quality recycling. It also mandates clearer labelling to improve waste sorting and recycling by consumers. Additionally, the regulation holds producers accountable through extended producer responsibility (EPR) schemes, requiring them to cover the costs of waste management and recycling for the packaging they place on the market. The PPWR seeks to minimise environmental impacts while fostering innovation in packaging materials and systems, promoting a shift towards a low-waste circular economy. Adopting a framework similar to the EU Packaging and Packaging Waste Regulation in Australia requires several key adaptations to align with the country's specific economic structure, regulatory environment, and market conditions.

Extended Producer Responsibility (EPR) (Kroepelien, 2000) **and Right to Repair (R2R)** (Productivity Commission, 2021) are key policy tools aimed at promoting sustainable consumption and waste reduction. EPR shifts the responsibility for managing products throughout their lifecycle—including disposal—onto producers, incentivising them to design more sustainable, recyclable, and reusable products. It ensures that companies bear the financial and logistical burden of waste management, encouraging the adoption of circular economy practices. Right to Repair policies complement EPR by empowering consumers and independent repairers to fix products through improved access to spare parts, repair manuals, and affordable repair services. These policies aim to reduce e-waste and extend product lifespans, addressing planned obsolescence and fostering a culture of repair. Together, EPR and R2R contribute to environmental sustainability by reducing resource consumption, minimising landfill waste, and promoting product stewardship across industries.

The EU Circular Economy Action Plan (CEAP) (EU Commission, 2020) is a key component of the European Green Deal, designed to accelerate the transition from a linear economy—where products are made, used, and discarded—towards a circular economy that promotes resource efficiency, waste reduction, and sustainable production. The CEAP focuses on the entire product lifecycle, targeting sectors with high environmental impacts, such as electronics, textiles, plastics, packaging, construction, and food. It aims to foster sustainable product design, improve waste management, increase recycling rates, and promote the reuse and repair of goods. The plan emphasises the importance of Extended Producer Responsibility, Right to Repair policies, and product passports to improve transparency and track materials. It also encourages innovation in circular business models and market incentives for circular products. By supporting the decoupling of economic growth from resource consumption, the CEAP seeks to position the EU as a leader in sustainability while reducing greenhouse gas emissions, minimising environmental impacts, and creating new economic opportunities and green jobs.

Japan's 4th Fundamental Plan for Establishing a Sound Material-Cycle Society (JMoE, 2018) outlines a national strategy to promote resource efficiency, waste reduction, and recycling, fostering a transition to a sustainable circular economy. The plan emphasises the 3Rs principle—Reduce, Reuse, Recycle—and extends it to include proper waste management and resource recovery. It aims to address environmental challenges by minimising material consumption, enhancing recycling technologies, and reducing dependency on virgin resources.

Key priorities of the plan include promoting product longevity and eco-design, expanding recycling systems for plastics and e-waste, and supporting industrial symbiosis to encourage resource-sharing between industries. The plan highlights the importance of decarbonisation, linking circular economy practices to climate goals by emphasising material efficiency as a way to reduce greenhouse gas emissions.

Japan's 4th Plan also introduces policies to promote public-private collaboration and community involvement, alongside regulatory frameworks to ensure compliance. To strengthen the transition, it integrates circular economy principles into regional and international cooperation, positioning Japan as a global leader in sustainable resource management. Through this plan, Japan aims to build a resilient, resource-efficient economy while addressing emerging challenges, such as plastic pollution and electronic waste, within a sound material-cycle society.

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