CIRCULAR ECONOMY KNOWLEDGE AGENDA

CEP TWENTE
CIRCULAR ECONOMY PLATFORM TWENTE

MAY 2024

UNIVERSITY OF TWENTE.

TABLE OF CONTENT

PREFACE

Circular Economy Platform Twente (CEP Twente) is a collaborative initiative between the academicians and students of the five faculties of the **University of Twente (UT)** and **Green Hub Twente**. It is founded by 16 circular economy enthusiasts from UT, with a seed fund granted by UT's **Climate Centre**.

The primary goal of the CEP Twente is to accelerate the transition towards a sustainable circular economy by fostering interdisciplinary research, education, and knowledge exchange. Next, we aim to act as a regional platform that provides room for collaboration among regional stakeholders, including municipalities, companies, and NGOs. The platform will serve as an umbrella association, bringing together diverse stakeholders from academia, industry, and government to build a community that shares a common vision and creates societal, environmental, and economic impact in the Overijssel region.

The CEP Twente envisions various activities such as knowledge-sharing events, research collaboration, grant application support, company tours for students, policy scenario projections, workshops for sustainable and circular technology diffusion, provision of challenging cases as real-life learning practices to different courses in our various teaching programs and experiential online learning activities. The main goal, in the long term, is to make the Twente region a sustainability exemplar for a climate-crisis-free future and connect with global circular economy initiatives.

"To make the Twente region a sustainability exemplar for a climate-crisis-free future and connect with global circular economy initiatives."

INTRODUCTION

Currently, our world is grappling with a pressing issue of unsustainable development that stems from the linear economy. This economic model, based on take-make-use-dispose, has led to the overproduction of waste and a scarcity of resources, which are posing significant threats to our future. It is alarming to know that almost one-third of all globally produced food goes to waste, while 90% of electronic waste continues to be dumped into landfills, causing adverse effects on both the environment and human health.

Moreover, industries such as construction and farming are contributing to the climate crisis by emitting large amounts of carbon and nitrogen, which further exacerbates the problem. Energy losses are also occurring due to a lower share of green energy resources and technologies, leading to increased greenhouse gas emissions.

One of the most significant contributors to these problems is the lack of circularity, which results in the depletion of valuable resources and excessive waste pollution. The scarcity and low circularity of critical raw materials such as lithium, niobium, and cobalt is a matter of concern for sustainable process and energy technologies, that heavily rely on these resources in order to fight against climate crisis. In fact, the Circular Economy Transition is a top priority for various national and international organisations, including the Dutch Government, the European Commission, the United Nations, and the World Business Council for Sustainable Development.

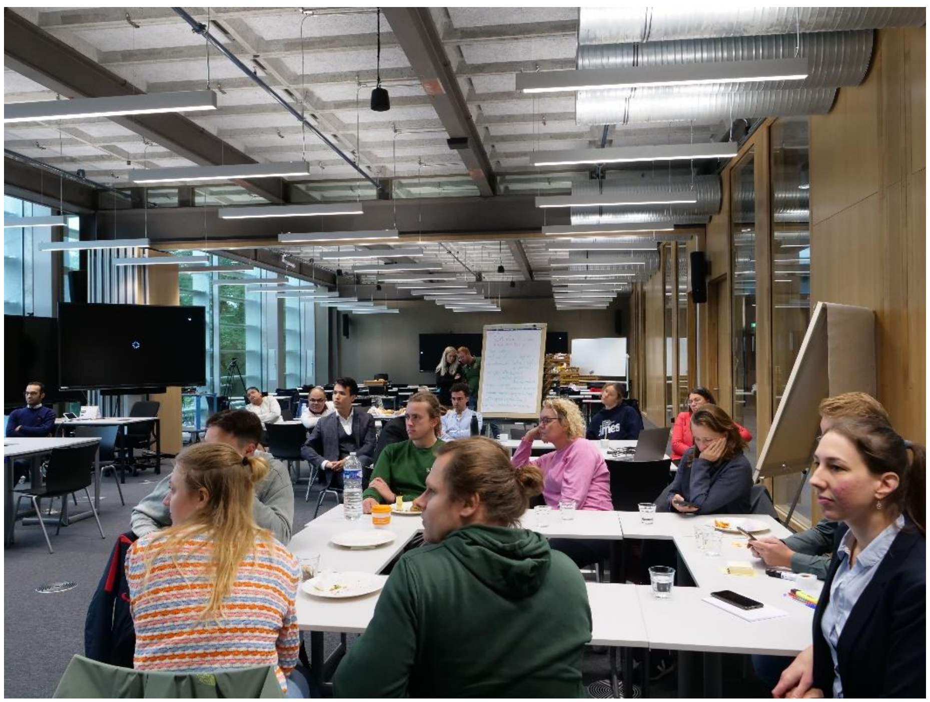
The Geo-Socio-Technical Approach For Sustainable Circular Economy Transition:

Circular economy transition requires the recognition of the interplay between geographical, social, and technological factors in achieving a sustainable (regional) development. Geographically, this approach takes into account regional contexts, resource availability, and spatial considerations to develop location-specific circular solutions, as well as applications such as digital twin development for the specific geographic locations being investigated from a circularity perspective.

Socioeconomically, it involves engaging stakeholders, raising awareness, and promoting behavioural change and acceptance of circular products and services to foster a circular mindset among individuals, businesses, communities, and organisations.

Additionally, the approach emphasises the importance of technological advancements, innovation, and the integration of digital tools and systems to enable the implementation and efficient operations of circular practices while optimising resource use, decelerating the climate crisis, and minimising its adverse impacts on natural and social ecosystems.

By considering the intricate connections between geography, society, and technology, the geo-socio-technical approach provides a comprehensive framework for driving the transition to a circular economy.



Objectives:

UT has a rich academic environment where academicians from different research backgrounds spend efforts on tackling global challenges in direct or indirect manners. Although we have multiple research groups in different faculties looking for solutions against unsustainable development and climate crisis, these are scattered and require developing an action agenda on transitioning to a circular economy. We aim to fill this gap and better steer the direction of the Twente region through a sustainable future in effectively and inclusively.

Therefore, CEP Twente is established as a collaborative initiative between the academicians and students of the five faculties of the UT including Green Hub Twente in 2023. The primary goal of the CEP Twente is to:

Accelerate the transition towards a sustainable circular economy by fostering interdisciplinary research, education, and knowledge exchanges.

Starting from 2024, we act as a regional platform which provides room for collaboration among regional stakeholders, including municipalities, companies, and NGOs. The platform will serve as an umbrella association, bringing together diverse stakeholders from academia, industry, and (local) government to build a community that shares a common vision and creates societal, environmental, and economic impact in the Twente region.

The CEP Twente envisions various activities such as knowledge-sharing events, research collaboration, grant application support, company tours for students, policy scenario projections, workshops for sustainable and circular technology diffusion, provision of challenge-based cases as real-life learning practices to different courses in our various teaching programs and experiential online learning activities.

Themes:

To address various priority areas aligned with regional, national, European, and global needs, CEP Twente establishes multiple working groups. These groups, aligned with the research activities at UT, focus on the preliminary themes as follows:

- Circular supply chain and product design
- Circular business models and finance
- Behavioural and social aspects of circular economy
- Circular energy systems
- Gamification and digital twins for circular economy
- Circular UT campus

We organised two workshops in 2023, the first one is on "Exploring circular economy solutions for a sustainable future" (12 October 2023) and the second one is on "Enacting solutions for a sustainable circular economy" (30 November 2023). The first workshop addresses the challenges against circular economy transition, while the second one explores how circular economy solutions can be implemented in practice. In this booklet, we summarise the key findings of these two workshops to formulate a knowledge agenda for circular economy from both practical and scientific perspectives.

1st WORKSHOP:

EXPLORING CIRCULAR ECONOMY SOLUTIONS FOR A SUSTAINABLE FUTURE

Approximately 50 people, including scientists, students, and support staff with diverse research and educational backgrounds joined the first workshop from all faculties of UT. Six roundtables took place in the workshop to identify the challenges of circular economy.

1.1. Circular Supply Chain and Product Design

For this roundtable, we started with an introduction round of the participants. Participants shared their views on design-related challenges for circularity. The main challenges are summarised as follows:

1. Design for disassembly: The participants emphasised the need to streamline the disassembly of products, making the process easier, faster, and more efficient. Automation was seen as a potential solution to achieve this, which would ultimately reduce the time and cost associated with recycling and reusing components.

2. Longevity and planned obsolescence: Participants recognized the importance of creating long-lasting products to combat the issue of planned obsolescence. They also discussed the challenge of rapidly changing (and shorter) product life cycles and suggested the possibility of regulations, such as bans on new releases, to slow down this trend.

3. Design strategies with reuse of materials: Design strategies that promote the reuse of materials were a focal point of the discussion. This extended to planning sustainable cities and repurposing existing structures, such as doors, in the construction process. Participants emphasised the role of raising awareness among people and highlighted examples like social housing initiatives and Fairphone.

4. Material transformation: With the example of recycling polymers, we came up with questions about how materials change through the recycling process and what impacts these transformations have on their usability and quality.

5. Link between product design and supply chain: The crucial connection between product design and the supply chain was a recurring theme, highlighting the need for alignment and coordination between these two parts for effective circularity.

6. Information exchange and standardisation: Participants raised concerns about the lack of information about what goes into a product and how it can be reused. Participants stressed the importance of standardization in design and material streams to address this gap.

7. Incentives and regulatory measures: The group discussed the role of incentives and regulatory measures/regulations in driving circularity. While incentives can encourage positive behaviours, regulatory "punishment" was considered for those who failed to meet sustainability goals.

8. Speeding up production without destruction: The challenge of accelerating production processes without harming the environment and product quality was addressed. Innovations in sustainable production methods were deemed crucial.

9. Prediction of material availability: Accurate prediction of material availability was recognized as a key factor in planning for sustainable products and supply chain design. This involves understanding the availability and scarcity of resources.

10. Product-as-a-Service, ownership (responsibility): Shifting towards a "product-as-a-service" model was suggested as a means of promoting responsible ownership and reducing waste. This approach would encourage consumers to see the products they use as a service with shared responsibility.

11. Risk assessment: The participants discussed the importance of risk assessment, not only from an environmental standpoint but also in terms of product value and longevity. Understanding the financial and environmental risks associated with products is essential for a circular design.

12. History of materials and buildings: The history of materials and buildings, particularly in the context of renovations and construction, was seen as valuable knowledge for making informed decisions about reusing and repurposing existing structures.

Another idea for a focus area that came up during the roundtable: **Explicit consideration of the supply chain topic.**

1. Materials and design: Participants emphasised the importance of replacing natural materials with recyclable and bio-based alternatives. They discussed the need for designs that balance between innovation and longevity.

2. Product lifecycle: There was an emphasis on designing products for easy disassembly and reflecting on the choice between mass production and consumer willingness to purchase refurbished items. The waste pyramid and the significance of the "refuse" step as the initial waste reduction method were also key points of our roundtable discussion.

3. Consumer behaviour and responsibility: The group discussed how to incentivize behavioural changes among consumers, the challenge of corporate responsibility, and the imperative need for a shift in business models to accommodate circularity. The interplay between costs and product pricing was a subject of intense debate.

4. Transition and integration: Transitioning to circularity was acknowledged as the most significant challenge, especially for established companies. Participants explored the idea of societal business models, the utilization of local materials, and the impact of raw material pricing. Communication, coordination, and the constant "balancing act" in this journey were mentioned. One question that centrally emerged here was: Where to start? Which analyses are needed? So we concluded the lack of expertise in this area.

5. Global and social considerations: Geopolitical and social considerations, such as the "living wage" discussion and issues around the mining of primary materials, were mentioned.

1.2. Circular Business Models and Finance

The motivations of participants exhibited a noteworthy degree of diversity, spanning from familial business interests to a commitment to transitioning towards a circular economy. Concurrently, various queries emerged concerning the financial framework of this transition, given that circular economy endeavours are often perceived as **lacking profitability**. This prompted a need for a more nuanced comprehension of the approach to and support for the implementation of circular business models within **real-world** corporate contexts.

The ensuing dialogues were systematically categorised into four key thematic areas: (1) Principles underpinning the Circular Economy, (2) Circular Business Models, (3) Financial Aspects of Circular Business Models, and (4) The Resilience of Supply Chains (both operationally and economically) within the context of Circular Business Models. Within these overarching "Themes," our primary objective was to encourage participants to identify and articulate the challenges inherent to these domains. Presented below is a concise summary of the discussions.

Challenges

1. How does one distinguish between the "adoption" of circular economy principles for existing businesses and newly established enterprises?

2. What are the potential implications, if any, for altering the core business proposition following the "adoption" of circular economy principles?

3. What is the precise step-by-step roadmap that companies should follow when transitioning towards a circular economy framework?

4. In what ways can managerial leadership contribute to the transition towards a circular economy?

5. What **financial strategies** should businesses operating in or transitioning to a circular economy contemplate for implementation?

6. What **methodologies** might be explored to ensure that all stakeholders within businesses can contemplate the adoption or transition to circular economy principles within their production processes?

It is worth noting that conclusive solutions to these questions were not reached during the discussions. However, **valuable insights** did emerge from our deliberations, which can be summarised as follows:

1. Management should actively promote and disseminate **business information** throughout their organisations.

2. **Training programmes and seminars** have the potential to dispel the lack of knowledge that companies, employees, and stakeholders may possess with regard to circular business models.

3. Consideration of **sociological and philosophical** dimensions is pivotal when contemplating the adoption or transition of business propositions or models. Questions about the extent of feasible change and the necessity of setting clear objectives are paramount.

4. Initiatives such as co-financing, risk assessment within networks, and the appointment of financial specialists to assess the **potential profitability** of transitioning to circular settings can greatly facilitate decision-making processes.

5. Engagement with all stakeholders along the supply chain is essential for gaining insights into prioritisation and the potential transformations required when transitioning to a circular model. Furthermore, it underscores the imperative of enhancing **supply chain resilience**.

1.3. Behavioural and Social Aspects of Circular Economy

Following the roundtable discussion on social and behavioural aspects of circular economy, three challenges have emerged.

1. Responsibility of Stakeholders: A crucial aspect to consider is determining how responsibility should be assigned within the framework of CE initiatives. The debate centres around whether a top-down or bottom-up approach should be employed. The cultural context in which CE is implemented plays a substantial role in deciding who bears responsibility for various aspects of the circular economy. This cultural factor can significantly influence whether decision-making and action are driven by the ecosystems/governments or initiated at the company/individual level.

2. Consumer Price Sensitivity: Another critical implication is the price sensitivity consumers exhibit. The success of CE hinges on how price-sensitive consumers are. Circular products may often be perceived as more expensive than their traditional counterparts. This can impact adoption rates and consumer acceptance, necessitating strategies to address or mitigate price sensitivity concerns or showing the benefit in the trade-off (e.g., higher price-higher personal benefit).

3. Ethical Implications: Circular Economy, while offering sustainable benefits, also raises ethical questions, particularly in specific sectors. Implementing CE principles in certain industries can lead to ethical dilemmas, challenging our preconceived notions of what is environmentally responsible. For instance, applying CE in healthcare might raise ethical concerns due to the industry's associated societal and economic pressure (e.g., fewer employees and cutting costs). The sector-specific ethical implications should be addressed as we transition to a more circular economy, recognising that responsible practices must align with broader moral values and principles.

1.4. Circular Energy Systems

In accordance with the circularity pyramid, a circular energy system should improve efficiency, reduce consumption where possible (energy efficiency), replace non-renewable resources, and avoid waste.

An energy system running on renewable energy, especially variable renewable energy from wind and solar, is not by default a circular energy system, since excess production of energy is often curtailed (evidence also suggests that increasing penetration of wind and solar energy is leading to more curtailment). There are several ways to utilize the excess energy, e.g., by demand response, energy storage technologies, hydrogen production or heat production.

Thus, a circular energy system should follow the concept of integrated energy systems/sector coupling to maximize the utilization of renewable energy, for instance, by linking the transport sector via hydrogen production and electric cars, as well as the heating sector through electrifying heat production.

Although many alternative pathways to improve circularity in an energy system exist, several challenges remain as follows:

Depending on the energy system, it is unclear which pathway is the best in terms of **economic feasibility, environmental impact, and user acceptance**. This stems from the fact that technologies are evolving, or are newly invented, and the operational performance is still to be investigated. Examples include:

Energy-intensive industries (e.g., metal production) are redesigning their processes to save energy and replace fossil fuels. But how efficient is this?

Excess wind power production can be used for hydrogen production, but is this option **economically profitable** or should the electricity be directly used?

The energy system is heavily interlinked with other possibly circular systems such as water and carbon. How do those systems **interact in the best way?**

What is the scope of a circular energy system? Where should be the boundary? The energy system spans a wide geographical area with the electricity grid (European transmission system) while circularity is typically considered as a more local concept.

How should an energy system be operated to be circular? For example, managing flows by accounting for the trade-off between economic and environmental goals? And how can the overall environmental impact be measured? This point can also be further linked to life cycle assessment methods.

Investments may be needed to make an existing energy system (more) circular. But **how should the existing system be changed, and are the investments profitable?** It can also be linked to circular financial models. Importantly, **who should undertake these investments: the power producer, network operator, utility, or municipality?** (link to stakeholder engagement) Or should all of them jointly invest? (link to the concept of non-ownership in circular economy). In the latter case, **how is profit redistributed?**

Finally, the production of renewable energy technologies (e.g., wind turbines, solar panels, batteries, and electrolysers) heavily depends on the supply of **critical raw materials** (e.g., lithium, nickel, cobalt, and copper) that are scarce in Europe. Circularity is very low here and recycling of old technology is not considered due to unprofitability. How can this be improved?

1.5. Gamification and Digital Twins For Circular Economy

Digital twins, the continuously updated virtual representations of physical products, systems, environments or processes, offer a pivotal bridge to circularity. They serve as dynamic testing grounds for various circular strategies and facilitate the seamless integration of circular principles at multiple scales. Potentially, digital twins contribute to circularity through three key aspects as follows:

1. Circular Product Design: Digital twins empower circular design by forecasting a product's end-of-life performance. They leverage real-time data to identify performance deteriorations and enable precise maintenance scheduling.

2. Resource Optimisation: In manufacturing, digital twins optimise resource consumption by providing a comprehensive overview of material flows. This analytical basis informs circular production management, improving efficiency.

3. Sustainable Urban Planning: At a city level, digital twins become invaluable tools for modelling the natural and behavioural impacts on infrastructure and landscapes in future scenarios. This enhances predictive decision-making in waste management policies, transport, energy and green infrastructure planning and shortens the policy implementation timeline.

Gamification Fostering Stakeholder Engagement

Digital twins serve as tangible demonstrative tools that foster multi-stakeholder participation. They encourage forward-thinking dialogues from diverse perspectives by prompting questions like "What if...?" These models create a trial-and-error environment for exploring the trade-offs that balance multi-stakeholder interests, bringing them closer to potential users, including industrial actors, governmental bodies, researchers, and citizens.

Furthermore, the unique features of digital twins make them ideal for gamification and educational purposes, allowing students to intuitively grasp the impact of their actions on complex systems despite temporal and spatial limitations. The human-model interactions stimulate student's interests and further help to unlock the potential of digital twins in the sense of learning by doing.

However, several **challenges** must be addressed to fully leverage digital twins for circularity:

1. Insufficient Circular Economy Knowledge: Incorporating circular economy principles into digital twin models necessitates a multi-disciplinary approach. Efficient data collection and sharing mechanisms must be developed to enrich the models further. Overcoming privacy concerns among private actors is essential to enable the comprehensive development and long-term maintenance of digital twins.

2. User Trust Gap: Bridging the trust gap between digital models and users remains a significant challenge. Stakeholders often question the reliability and applicability of digital twins, even if the models are highly accurate. Thus, establishing trust and enhancing user acceptance in digital twins are vital.

3. High Resource Investment: Developing, evaluating, and maintaining digital twin models requires a professional team and substantial economic investments in devices and technical experts.

To address these challenges, potential sub-themes include focusing on **data for circularity** as a separate theme and emphasising **policy and governance for circularity** to complement existing circular economy efforts. These measures can facilitate the broader integration of digital twins and gamification in the context of circular economy decision-making, engaging actors with diverse educational and skill backgrounds.

1.6. Circular UT Campus

In this roundtable, we conducted a more practice-oriented discussion to convey clear and actionable messages that fit staff with different educational and skill backgrounds at the campus.

Campus and Facility Management has a programme which focuses on making the operational management of UT sustainable (this is called the SEE Programme). There is a sustainability policy in which for all 10 themes mentioned in SEE we have described goals. One of the goals is to become a circular campus. This is aligned with the national goal of the Dutch government.

But, it is not yet known how to become circular. What are high-impact areas for UT? What should we focus on?

We would like to develop a roadmap on **how to become a circular campus in 2050, or earlier as a university can serve as an example to the region.** We know there is a lot of knowledge within UT. We would like to collaborate and use the knowledge at UT to make UT circular. We invite staff and students to work with us on this.

During the roundtable, we asked participants: What does "a circular campus" mean to them? What should be the focus areas?

1. Waste Management and Recycling: Implement comprehensive waste management systems to ensure all waste generated on campus is either recycled or reused locally whenever possible. This includes organic waste, paper, and electronic waste.

2. Green Maintenance and Biodiversity: Source maintenance materials locally and sustainably, minimising the use of external inputs like fertilizers. Prioritize biodiversity in landscaping and campus design.

3. Water Conservation and Management: Develop systems to capture and store rainwater for later use on campus, reducing reliance on external water sources.

4. Circular Consumption of Electronics: Explore strategies to extend the lifespan of electronics through repair and reuse programs. Implement policies to discourage frequent upgrades and promote responsible consumption.

5. Circular Water Systems: Invest in wastewater treatment facilities to create a closed-loop water system on campus, minimising water waste and environmental impact.

6. Sustainable Procurement and Consumption: Evaluate the environmental impact of all purchases, including food, electronics, and office supplies. Consider implementing a true pricing model to account for environmental costs.

7. Student Engagement and Living: Engage students in the circular campus initiative by involving them in decision-making processes and providing opportunities for sustainable living on campus.

8. Research-Practice Integration: Ensure that UT's research on circularity translates into real-world practices on campus, serving as a model for the region.

9. Resource Sharing and Swapping: Establish locations on campus where students and staff can swap items like phones, clothes, and furniture, reducing waste and promoting reuse.

10. Transparency and Education: Provide clear information on the disposal and recycling of electronic waste and encourage responsible behaviour through educational initiatives.

11. Efficient Data Management: Address inefficiencies in data storage and management to reduce duplication and waste.

12. Digitalisation of Academic Processes: Encourage the digital submission and review of academic documents to reduce paper waste.

13. Sustainability Training: Integrate sustainability and circularity training into the curriculum for both students and staff, fostering a culture of environmental responsibility.

14. Engagement with Study Associations: Collaborate with student associations to promote sustainability initiatives and gather ideas for improvement.

15. Behavioural Change: Encourage sustainable behaviours among the campus community, such as waste reduction, proper disposal, and resource conservation.

16. Optional Gifts and Amenities: Offer employee and student gifts on an opt-in basis to reduce unnecessary consumption and waste.

17. Energy Efficiency: Address concerns related to excessive screen brightness and energy consumption, particularly with outdoor displays.

18. Communication and Awareness: Continuously inform and engage students and staff about ongoing sustainability efforts and opportunities for involvement.

By focusing on these areas and engaging the UT community in the process, the university can make significant strides toward achieving its goal of becoming a circular campus by 2050.

2nd WORKSHOP:

ENACTING SOLUTIONS FOR A SUSTANABLE CIRCULAR ECONOMY

Around 40 participants from industry, government, and academia, joined the second collaborative workshop. After the general opening, roundtable coordinators presented the highlights of the first workshop, respectively. These highlights were presented in the form of a real-time voting session where participants can rank the urgency and importance of the summarised highlights. By discussing the priorities of different CE challenges, we link the prior workshop and unfold the future solutions for a sustainable circular economy.

2.1. Circular Supply Chain and Product Design

For this roundtable, participants from academia and diverse industries first introduced themselves. We first asked the participants to indicate in which industry they work or are interested. Then we made an inventory of examples of circular products, of which we selected infrastructure, plastics, electronics and bikes. For these product categories, we brainstormed on several design strategies that can be used to enact circular economy solutions for the transition from identifying challenges to crafting actionable solutions.

The workshop not only built on the identified challenges from the first workshop but also fostered a collaborative environment where actionable solutions were envisioned for a circular and sustainable future in each product category. The discussions revealed the need for innovative business models, simplified technologies, and a shift in consumer ownership paradigms to fully embrace the circular economy. The outcomes in detail can be summarised as follows:

Bikes:

1. New business models: The discussion in the bike category revolved around exploring new business models for the industry. Shifting from ownership to an "as-a-service" model was mentioned as a potential solution. Swapfiets was mentioned as a prominent example.

2. Simplification (low-tech): Considerations were made for simplifying bike designs, and balancing the complexity with technological and material simplicity.

3. Return and disposal logistics: Participants explored practical aspects of returning and disposing of bike products in a circular economy.

Electronics:

1. Energy-intensity of recycling: Discussions went into the energy intensity of recycling processes for electronics, exploring the trade-offs involved.

2. Policies for product lifetime: Considerations were made regarding policies, such as mandatory product replacements after a certain period, to address electronic waste.

3. Grid-based systems: Participants explored innovative alternatives like grid-based systems as a sustainable approach to traditional batteries.

(Disposable) Plastics:

1. Design for disassembly and modularity: Strategies such as designing for disassembly and modularity were proposed to tackle the disposable plastics challenge.

2. Reusable materials: Participants highlighted the importance of promoting reusable materials in plastic products.

3. Plastics as-a-service: Innovative business models like "Plastics as-a-service" were discussed as a potential solution, challenging the traditional ownership model.

4. Repurposing and avoiding material mix (design for recycling): The brainstorming included ideas for repurposing plastics in different settings and avoiding material mix to facilitate recycling.

Infrastructure:

1. Reliability and safety of recycled materials: Participants emphasised the need to address concerns related to the reliability and safety of recycled materials in infrastructure projects.

2. Construction methodology: Discussions focused on exploring construction methodologies, questioning the feasibility of realistic approaches for long-life buildings, and aiming for sustainable and resilient structures.

3. Lifetime flexibility: The concept of lifetime flexibility (for example, adaptable houses), was considered for infrastructure projects, reflecting a forward-looking approach.

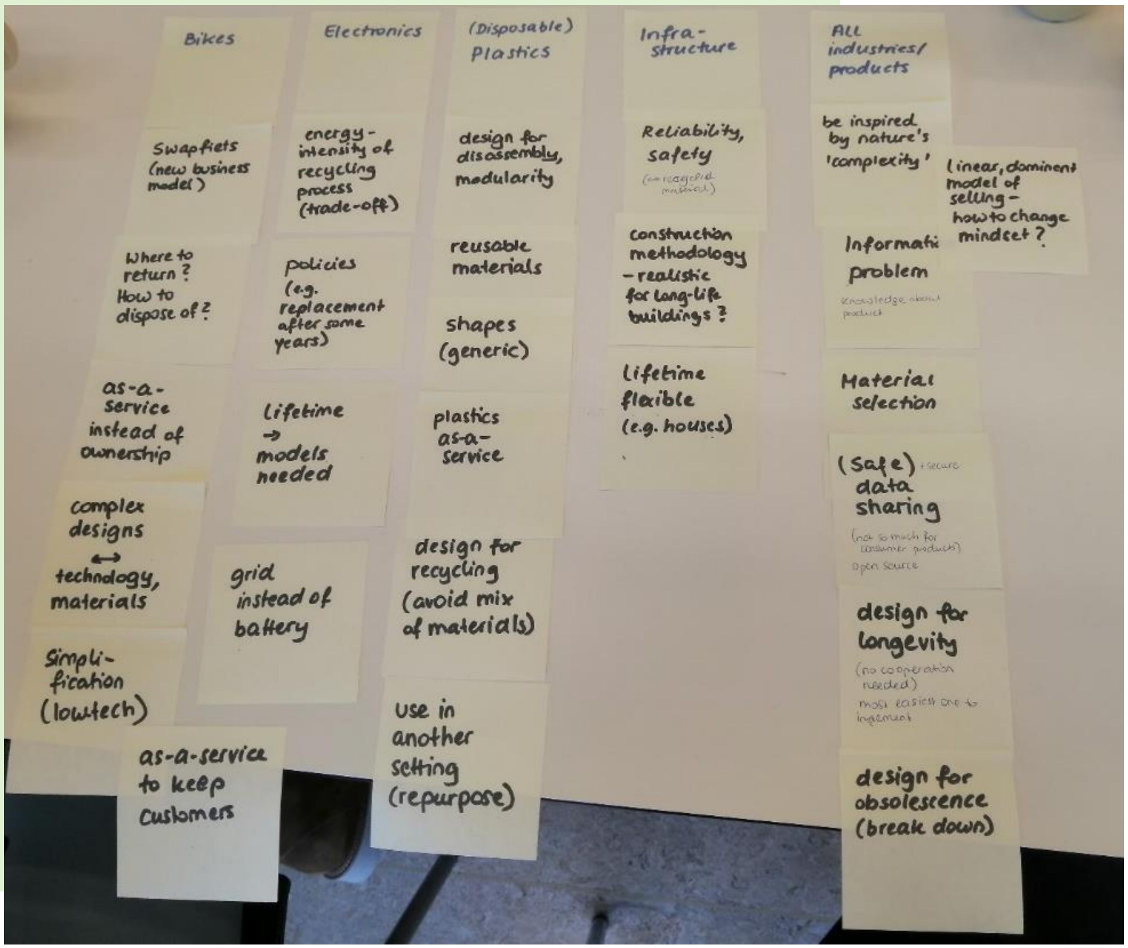
Cross-Industry Insights:

Across all product categories, there was a shared emphasis on being inspired by nature's complexity, addressing information challenges, and selecting materials thoughtfully. Participants highlighted the crucial role of knowledge about products in the circular design process (“information problem”: Where to return? How to dispose of a product?). The selection of materials emerged as a key consideration, with an emphasis on ensuring safety and security, especially in the context of recycled materials.

Summarised, the addressed key strategies mentioned were:

- A shift toward circular business models;
- Open-source solutions (data-sharing initiatives);
- A commitment to the design for longevity as an easily implementable strategy (“low-hanging fruit” requiring minimal cooperation).

Collection of post-its with solution strategies (the outcomes of brainstorming with participants):



2.2. Circular Business Models and Finance & Behavioural and Social Aspects of Circular Economy

In this roundtable, we combined two different topics: “Circular business models and finance” and “Behavioural and Social Aspects of Circular Economy”. The in-depth discussion focused on **financial and behavioural** drivers in CE. Important considerations were given to the economic incentives and disincentives for businesses to move towards the adoption of circular models and the role of various stakeholders in this process.

A significant topic that emerged was **whether companies could produce circular products without implementing circular business models**. This critical question necessitates further exploration. It raises another point: Should we intentionally design products and services within business models for CE, rather than rely on CE happening by chance? The efficacy of financial incentives for encouraging this transition was also a key focus.

In the minor discussion, several pertinent questions were raised: Is the **affordability of CE products** still a major concern? How much reliance should we place on government institutions to facilitate these transitions? Moreover, the effectiveness of individual actions, like those of consumers and government (e.g., citizens), in driving substantial change was also debated.

2.3. Circular Energy Systems

The roundtable discussion on Circular Energy Systems (CES) was held to explore some of the crucial challenges related to achieving circularity in energy systems, identify solutions, and understand how to drive these discussions towards actionable outcomes. The dialogue emphasised two primary objectives of CES, namely:

(1) The Circularity of the Materials Used in Energy Technologies;
(2) The Circularity of the Energy Flows Themselves.

Materials: Despite the big success in reducing the cost of low-carbon technologies such as wind turbines, solar panels, electric vehicle motors and energy storage systems, little has been done to ensure that the materials employed are recycled and reused. In other words, these technologies/products have not been designed to be circular, which is an issue becoming more and more relevant now that many such units are reaching the end of their lifetime.

For instance, solar panels went mainstream in the early 2000s and have a lifetime of about 25-30 years, so millions of units are now being decommissioned. In this process, special attention should be given to critical raw materials and rare earth elements used in energy technologies including cobalt, copper, nickel, and lithium, some of which are **particularly scarce in Europe** and exhibit rising prices. The concepts from circular product design can be employed to address these issues (see roundtable on circular product and supply chain design).

Flows: A significant portion of the energy generated, including renewable energy, is wasted. For instance, managing an increasing penetration of renewable variable sources in the systems is complex and leads to more and more curtailments, if demand and supply can not be matched. To reduce curtailment, this electricity could be stored, or repurposed by converting it to hydrogen or heat, and then either stored in these forms (which is easier to do for longer times compared to electricity) and/or used for transport or heating.

This highlights the important role of **sector coupling** (i.e., integrating different parts of the energy sector like electricity, heating, and transport) to enhance the circularity of energy systems and minimise waste. Designing and operating such a complex and integrated system in the most sustainable and cost-effective manner requires frameworks to evaluate investment options and operational decisions. Such frameworks can be based on simulation, optimisation, machine learning, forecasting, or more in general **artificial intelligence techniques**. For instance, real option models can analyse higher-level investment choices while digital twin environments in combination with mathematical optimisation can simulate and dynamically optimise technology operations and the related energy flows.

Infrastructure Expansion

Another topic covered was the necessity of upgrading and expanding infrastructure, such as **expanding the power grid** (e.g., in the Netherlands, the grid is rather congested due to the quick electrification of transport) and pipelines for heating to ensure the efficient distribution of excess energy. However, losses in energy conversion and distribution have a big impact and should be reduced. The discourse thus leaned towards advocating for localized CES concepts to minimise losses over shorter distances than focusing on a national concept.

Finally, the inherent flexibility of CES was highlighted as a key feature. It can be enhanced through investments in batteries, waste heat utilization, and demand response mechanisms. The discussion also focused on selecting **battery technologies**, e.g., by comparing lithium and salt-water batteries. While the former is significantly smaller, the latter reduces reliance on critical materials.

To summarise, the main insights from the roundtable covered the complementary pathways in ensuring materials and energy flow circularity, the feasibility and challenges of infrastructure expansion for CES while accounting for losses, and the investment plans for enhancing flexibility, with a focus on battery technologies.

2.4. Gamification and Digital Twins for Circular Economy

This roundtable delves into leveraging digital twins and gamification to advance the implementation of CE. As shown in the first discussion session, participants agree that digital twins can be used as a powerful tool to test and demonstrate the feasibility of circular practices. The combination of digital twins and gamification helps to create a virtual environment where government officials, citizens, and professionals seek circular collaborations based on a **shared vision.** This virtual environment is primarily a dynamic and interconnected digital representation of physical products, assets, processes, and systems varying at different scales.

It provides three key functions to support CE transition including:

1. Scenario Simulation and Visualisation

Simulation capabilities allow for scenario testing and the visualisation of potential outcomes, facilitating decision-making at early design phases. Integrating gamification into digital twins can influence and shape behaviours related to circular practices. By creating simulated environments similar to games, individuals and professionals can gain insights into the potential consequences of their decisions, fostering a better future-oriented understanding of CE.

2. Real-time Supply Chain Monitoring and Coordination

By continuously updating and analysing data, digital twins provide valuable insights into the performance of CE initiatives. This data-driven approach helps identify areas for improvement, ensures the relevance of models, and contributes to the ongoing optimisation of circular practices. On a larger scale, it enables real-time monitoring of processes and resources, facilitating effective coordination in smart circular ecosystems.

3. Trade-off Learning and Stakeholder Engagement:

Sustainability and CE challenges are often about trade-offs. Digital twins provide a platform for assessing trade-offs between different CE values and factors. This includes balancing economic considerations, environmental impacts, and social aspects. The combination of digital twins and gamification helps to **visualise and analyse** these trade-offs. Furthermore, it offers a platform to teach students, professionals, and the broader community about CE principles. Through **interactive simulations**, users can learn how to navigate challenges, manage resources sustainably, and address the complexities inherent in circular practices.

Gaps Between Simulation and Reality

However, there is always a gap between the virtual and real versions of reality. Participants are concerned about the accuracy and comprehensiveness of the model. **Simulation results interpretation** is crucial to explain how the model outcomes would actually make impacts in reality, and safeguard the final last mile decision support. Nevertheless, roundtable experts agree that there are always mismatches between the model and the reality.

To tackle this challenge, we need to deconstruct a complex system into reachable sub-components and identify a suitable level of detail to start the model development. The key is to create a **joint-force team** that can perform a development and evaluation cycle iteratively, instead of delivering a “perfect” model at the first trial. Finally, the roundtable session ends with an agreement that the combination of digital twins and gamification is a powerful analytical tool to align diverse CE visions, analyse potential CE intervention effects, and foster **cross-boundary CE collaborations** at scale.

2.5. Circular UT Campus

Based on the two workshops, the key action points that can contribute to an actionable roadmap for implementing a Circular Economy at the UT campus are summarised into seven categories as follows:

1. Purchasing:

- Establish agreements with suppliers to prioritise recycled materials and sustainable production methods.
- Integrate circularity considerations into procurement processes, adding an extra step at the contract stage to ensure sustainability criteria are met.
- Encourage smart purchasing practices to minimise waste and resource consumption.
- Advocate for tenders that promote circularity and less resource-intensive production methods.

2. Buildings:

- Implement sustainable building practices based on ongoing research findings, for instance, the successful circular building project of Langezijds renovation at the campus.
- Ensure that UT's campus infrastructure reflects the university's commitment to circularity and sustainability.

3. Energy:

- Explore opportunities to establish positive energy districts within the campus, aligning with EC's objectives.
- Shift focus from purely technical solutions to holistic approaches that consider social factors in energy planning.
- Position UT as a pioneer in adopting innovative energy structures that prioritise sustainability and circularity.

4. Food:

- Promote plant-based and vegan food options as the norm rather than the exception.
- Implement solutions such as biodigesters to address food waste and minimise environmental impact.
- Collaborate with suppliers and stakeholders to optimise food supply chains and reduce waste throughout the process.

5. Electronic Waste Management:

- Raise awareness about the importance of proper disposal and recycling of electronic waste among staff and students through targeted campaigns.
- Simplify the process for returning old electronics on campus, providing clear guidelines and collection points.
- Establish a repair shop on campus staffed by volunteers to refurbish and extend the lifespan of electronics.
- Facilitate the sharing of lab equipment and resources among research groups to minimise duplication and promote resource efficiency.
- Centralize information on second-hand furniture availability to encourage reuse and reduce unnecessary purchases.

6. Behavioural Change and Awareness:

- Engage the UT community through education and awareness campaigns to foster a culture of sustainability and circularity.
- Encourage staff and students to participate in circular initiatives by making it easier to access resources and services that promote reuse and recycling.

7. Monitoring and Evaluation:

- Establish metrics and tracking mechanisms to monitor progress towards circularity goals.
- Regularly review and assess the effectiveness of implemented strategies, making adjustments as needed to optimise outcomes.

By following this roadmap and actively involving the UT community in the process, the university can make significant strides towards a circular campus and setting an example for sustainability in the region.

ENDING REMARKS

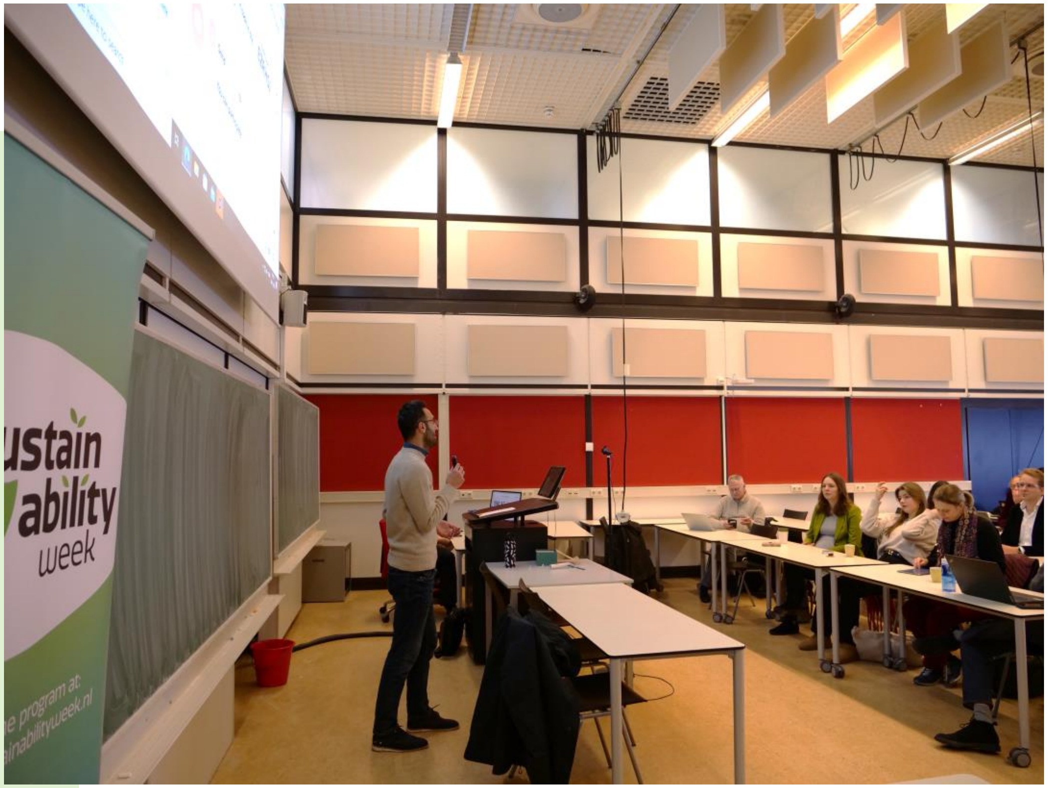
The concept and practice of Circular Economy (CE) offer an integrated approach to sustainable development in diverse sectors. To foster cross-sectoral CE, it is important to collaborate with different stakeholders and create a common shared vision. This booklet is a stakeholder communication material that records two workshops held at the campus of UT according to the proposal plan of CEP Twente.

We highlighted the CE challenges and action points based on six themes, namely, (1) Circular supply chain and product design, (2) Circular business models and finance, (3) Behavioural and social aspects of circular economy, (4) Circular energy systems, (5) Gamification and digital twins for circular economy, and (6) Circular UT campus. All together, these themes unfold a comprehensive landscape of research agenda on CE. We share this booklet with a wide range of audiences to call for inter-disciplinary research and action. Given the importance and complexity of the CE transition, we also intend to refine this booklet based on further validations and ongoing stakeholder consultations. We envisage expanding the community of CEP Twente and continuously generating collaborative momentum for CE transition at scale.

Organisations interested or involved in the CEP Twente events are invited to send their suggestions and feedback on this booklet to the email address as follows:

CEP Twente

Email: ceptwente@utwente.nl



ACKNOWLEDGEMENT

This booklet is created with the cooperation of the following individuals:

Devrim Murat Yazan[1]: CEP Twente coordinator

Patricia Rogetzer[1], Marc van den Berg[2]: Circular supply chain and product design

Marcos Machado[1], Mahak Sharma[1]: Circular business models and finance

Letizia Alvino[3], Hao Chen[1]: Behavioural and social aspects of circular economy

Daniela Guericke[1], Alessio Trivella[1]: Circular energy systems

Yifei Yu[1], Mila Koeva[4]: Gamification and digital twins for circular economy

Birgit Dragtstra[5], Brechje Marechal[5]: Circular UT campus

[1]Industrial Engineering and Business Information Systems Section, High-tech Business Entrepreneurship Department, BMS Faculty
[2]Civil Engineering and Management Department, ET Faculty
[3]Entrepreneurship, Technology, and Management Section, High-tech Business Entrepreneurship Department, BMS Faculty
[4]Department of Urban and Regional Planning and Geo-information Management, ITC Faculty
[5]Campus & Facility Management, UT

CEP Twente acknowledges the members of **GreenHub Twente** for their immense contributions to the organisation of the workshops.

CEP Twente acknowledges **UT Climate Centre** for providing seed funding for the organisation of workshops.

CEP Twente acknowledges all the workshop participants for their active engagement.

TWENTE
CIRCULAR ECONOMY PLATFORM TWENTE

UNIVERSITY OF TWENTE.