Royal Academy of Engineering

Symposium report

Frontiers symposium

The circular economy

30 April to 2 May 2018 | London, UK

Royal Academy of Engineering

Introduction to the Frontiers symposia

The Frontiers symposia bring together around 65 of the best early- and mid-career researchers and practitioners from industry, academia, NGOs, and the public sector in multidisciplinary workshops that address fundamental development challenges.

The objective of the symposia is to encourage collaborative work that addresses international development challenges and to promote cross-disciplinary thinking among the next generation of engineering leaders.

Competitively allocated seed funding is available to strengthen the collaborations developed at the symposia.

Contents

Symposium

Delegates met for three sessions over 2.5 days interspersed with networking opportunities, receptions and dinners, held at the Royal Academy of Engineering, in London, UK.

Frontiers insights: the circular economy

This report summarises discussions from the Royal Academy of Engineering Frontiers symposium: The Circular Economy, in May 2018. Insights were collected during a dedicated session that summarised discussions from workshops over the two previous days. The symposium was chaired by Professor Adisa Azapagic FREng, professor of sustainable chemical engineering at University of Manchester, and Dr David Greenfield, Managing Director of SOENECS and Organiser of the Circular Economy Club, London.

The symposium theme considered the opportunities and challenges that moving towards a circular economy can pose in different contexts. Broadly understood, a circular economy sees products and materials recycled, repaired, and reused, and waste from one industrial process becomes an input into another.

In settings where resource use is damagingly high, there is much to learn from lower resource settings in the context of the circular economy. Limited access to resources fosters an approach to materials and products that uses less and extends the life of a product as much as possible. Supply chains and systems tend to be much more localised, and people are often very innovative and flexible in how they use products and services. This symposium brought together innovators, researchers, and thinkers from a range of different countries to learn from each other's examples and make new connections around the globe.

The symposium brought an interdisciplinary approach to circular economy discussions by bringing together engineers and non-engineers from a wide range of backgrounds and sectors. Participants found that this offered valuable new perspectives and new ideas about potential solutions emerged as a result. It is expected that these interactions will cross-fertilise ideas through new networks that have impacts beyond the event and around the world.

The event was centred around three sub-themes of the circular economy: Designing for Circularity, Learning from Natural Systems, and Dematerialisation. Outside of discussions, highlights of the event included a boat trip on the Thames to help participants meet in a less formal setting, and a networking reception and dinner at the Barbican Centre Conservatory with guests from the London Circular Economy Club and a speech from Chief Scientific Advisor to The Department for Environment, Food and Rural Affairs (DEFRA), Professor Ian Boyd FRSE. Professor Boyd captured the spirit of the room by noting how waste is an international problem, requiring coordination on a global scale.

Dr David Greenfield, Managing Director SOENECS

David is the Managing Director of SOENECS Ltd (SOcial, ENvironmental & EConomic Solutions), an independent environmental research and advisory practice that he set up in 2014 following 15 years in leadership roles in local and regional government. He provides strategic advice and support to the public and private sectors and specialises in the fields of circular economy, waste management, resource management, climate change, renewable deployment, carbon management and partnership delivery.

Professor Adisa Azapagic FREng, professor of sustainable chemical engineering at University of Manchester

Adisa leads Sustainable Industrial Systems, a multidisciplinary research group working in close collaboration with industry, policymakers and other stakeholders to help identify and implement sustainable solutions to current sustainability challenges (www.sustainable-systems.org.uk).

She is the founding Editor-in-Chief of *Sustainable Production and Consumption* and Editor-in-Chief of *Process Safety and Environmental Protection*. She has received several awards for her research, including the Institution of Chemical Engineers Award for Outstanding Achievement in Chemical and Process Engineering, and GSK Innovation Award for masterminding the carbon footprinting tool CCaLC (www.ccalc.uk.org).

Designing for circularity

Session chairs

Catherine Joce, Cambridge Consultants and Kerry Kirwan, University of Warwick

Presentations

1. How do we embed design principles into practice?

   Alex Moreno, FiqueTex Colombia

2. Can designers really make a difference?

   Jamie O'Hare, University of Bath

3. Business as unusual – how business is embracing the circular economy.

   Catherine Joyce, Cambridge Consultants

Key insight:

- Designing for circularity requires lifecycle thinking, a systems approach and stakeholder engagement.

Summary and recommendations

A circular economy model is disruptive to the status quo, and if it is to be successfully adopted and optimised then multiple stakeholders and production and consumption systems will be affected. Most participants agreed that while the impact on most stakeholders is likely to be positive, there will inevitably be some who feel they are losing out in some way. Careful engagement of stakeholders and considering the consequences of the new model in the design phase will be critically important for success.

Recommendations:

- When designing a project, consider potential trade-offs in the order that the system is prepared for them, or so that they can be designed out. This requires clear articulation of the relative costs and benefits to each stakeholder who will need to be on board for the product or model to be successful.
- Policy incentives will create the motivation to shift to a circular economy. Investors in linear business models prioritise return on investment, while circular economy business models must consider how profits are redistributed back to local communities in an equitable way. Therefore, policy incentives for a new mindset in business value creation are essential.
- Local systems for production and consumption must be designed and engineered so that products are easily returned for remanufacture. This is especially important in the case of critical raw materials.
- Manufacturing models should be designed to support circular economy principles. Considerations of scalability, flexibility and distributed manufacture in the design phase allow the model to start small and grow with demand. Local assembly of a product can be a compromise in globalised systems. Factories should have low energy needs and the ability to reuse waste where possible.
- Innovative business model designs must consider as many aspects as possible. For example, multifunctionality and sharing or ‘servitisation’ can boost resource efficiency, and local distribution systems can be made smarter by using e-mobility or drones.

Discussion

In the discussion, participants discussed whether critical raw materials can be "designed out". One suggestion was for designers and engineers to rely on sourcing local materials.

The example of factory design was discussed to consider how the design could support circular economy principles, for instance facilitating the use of materials in the factory. In this case, it was considered important to start small and scale up as needed. Furthermore, production facilities are needed where there are markets so that end of life products can be taken back. As one participant noted, within one centralised global production system it is difficult to reverse logistics but in local, smaller systems it is much easier to reverse logistics.

Technology is leading to the creation of new multi-functional products, increasing the utilisation of products while also increasing production. For instance, intelligent vehicles and drones are helping to distribute products. The group discussed whether it is possible to cascade the use of products into secondary markets, such as a parent passing their mobile phone down to their children.

Presentations

How do we embed design principles into practice?

Alex Moreno, FiqueTex Colombia

Alex highlighted ways to embed design principles into practice with circular economy principles, using his own experience.

With a background in textile engineering, Alex noticed an opportunity to reduce the environmental impact of fique plant production. The plant is common to Colombia and cultivated for its fibres. However, traditional methods resulted in most of the plant going to waste. Along with his son, Alex developed Fiquetex—a company that makes use of the waste from fique plants to produce textiles. The end product is a biodegradable leather and fabric that have a smaller environmental impact than traditional textiles and that provides work for local farmers,

In Alex's experience, designing for circularity requires considering several elements, including:

- **Using regenerative resources:** Plants such as the fique or rubber trees, for example, can be produced to support local ecosystems and communities.
- **By using the right materials:** In the case of fique fibre and latex, they can be not only sourced from sustainable producers, but they also fit the need that Fiquetex aims to solve: they can be turned into high-quality textiles.
- **By designing for an appropriate lifetime:** Fiquetex's final products, fique fibre and natural rubber latex bags, are sustainably produced and durable while also being compostable. Though they do not last indefinitely, Alex's company has considered the impact of their product once its lifetime is complete.

There are many benefits to proving impacts:

- **Economic:** value for money products, competitive prices
- **Social:** communities involved gain from impacts such as national development
- **Sustainable:** Sustainable, renewable and compostable materials, CO2 emissions.

"Circular economy requires lifecycle thinking and a systems approach to avoid conflicts and optimise the system."

Can designers really make a difference?

Jamie O'Hare, University of Bath

At the core of Jamie's presentation was the concept of 'sustainability hotspots' or areas of biggest environmental impacts along a product's lifecycle. By identifying these hotspots, designers and engineers can understand where they can make the most change and develop a strategy to address them.

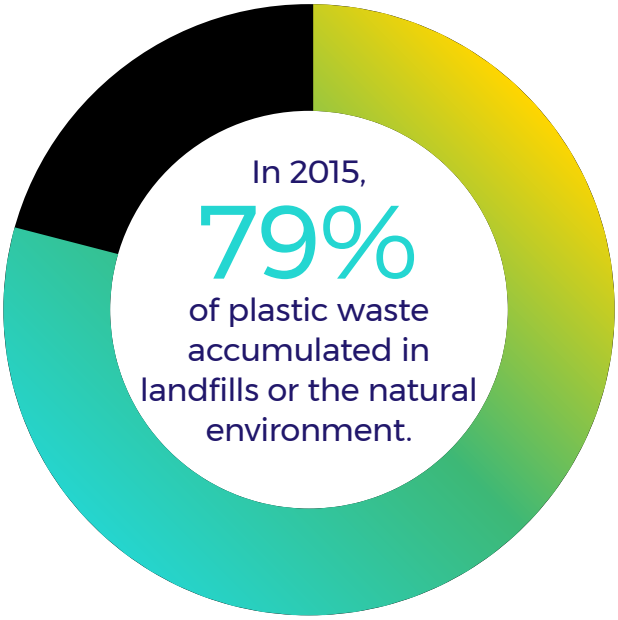
However, Jamie emphasised the need to identify potential hotspots in the planning phase of new projects. Once designers understand different sustainability hotspots, they can generate sustainable product ideas. For instance, an eco-audit can be a helpful tool as it assesses the impacts of all the different inputs and outputs for a project such as the amount of CO2 produced. Using this data, designers can create projects that minimise the environmental impact of the materials used, the manufacturing process, the transportation, the outputs coming from product's use such as electrical losses, and the product's disposal.

Designers can incorporate circularity from the beginning of a product's development, from generating ideas to selecting the right materials. However, Jamie underlined the need for designers to identify business models that help circular design to work.

Business as unusual – how business is embracing the circular economy

Catherine Joce, Cambridge Consultants

Circular economy provides a framework for businesses to combat resource dependency challenges. The circular economy model aims to use resources to their maximum value and to 'design out' waste from the system. In practice, this means creating products that last longer, can be repaired, upgraded, remanufactured or recycled while building accompanying business models. To illustrate this, Catherine shared real examples from work undertaken by Cambridge Consultants.



Closing the loop on food waste

Food waste contributes an estimated 7% to global emissions. Cambridge Consultants developed a fully automated waste processing system using larvae to convert tonnes of food waste (per day) into high-value protein feedstocks. Container-sized modules were deployed at the source of the waste such as supermarkets, which eliminates food waste transport costs, and the model can be easily scaled to meet seasonal variations.

PHA bioplastics

In 2015, approximately 6300 Mt of plastic waste was generated, around 9% of which was recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment. Cambridge Consultants conducted a market analysis to identify current and future applications of bioplastics including materials substitution and innovation applications. This included an evaluation of PHA properties and design considerations, and the mapping of PHA supply chains to identify key materials suppliers and manufacturing considerations.

Smarter recycling

Over eight billion PET bottles and three billion coffee cups are disposed of in the UK each year. Cambridge Consultants developed a smarter recycling system to improve recycling rates and quality. This included:

- Machine vision and machine learning, to train the recycling system to recognise new items over time
- Consumers using the smarter recycling point were 35% more likely to dispose of waste items correctly than those using a traditional bin
- The end-of-life touchpoint extends a brand's customer engagement and reduces the loss of recyclable materials to landfill.

Learning from natural systems

Session chair

Richard MacCowan, Biomimicry UK

Presentations

1. Biomimicry, resilience and sustainability

   Julie Winnard, Haynard Ltd.

2. Exploiting Nature as Processes and Algorithms

   Rupert Soar, Nottingham Trent University

3. Learning from natural systems

   Giorgos Masourekkos

Key insight:

- Nature has much to teach engineering. Engineers should work with biologists to understand and take inspiration from natural systems.

This session explored how nature solves problems - sometimes in ways that are contradictory to what we expect. Participants were invited to open their eyes to structure, space and time – the key ways that nature solves problems. Richard MacCowan invited the symposium to explore the complex science around the 'how' and 'why' functions occur and make systems work.

Summary and recommendations

Nature is a fantastic problem solver. For example, it can transport things, keep things warm and secure, and is incredibly energy efficient. Engineers have much to learn from biology and could benefit from working collaboratively to understand and investigate the processes that natural systems use and explore how they could inspire similar principles to make engineered systems more efficient.

"Innovate by looking at, and understanding, the processes involved, and then look to nature for inspiration!"

Recommendations:

- Take time to understand natural processes that can reveal solutions, for example by exploring natural substances and materials, storage solutions, use of space, time and energy, modes of storing and using information, and self-repair.
- Accept that there is no such thing as a perfect system or solution, but that understanding how the natural world solves problems can give valuable insights for better engineering solutions.
- Nature is an imperfect database and extracting information from it comes with challenges as well as opportunities. An approach that can yield success is to understand the existing solution and reverse engineer it to work out the biological processes
- The next generation of engineers should be inspired and equipped with the skills to use nature as a template for engineering solutions. The current generation needs to show them that this way of thinking exists through examples that they can touch – like an egg or a sunflower.

Presentations

Biomimicry, resilience and sustainability

Julie Winnard, Haynard Ltd.

Julie Winnard discussed how some of the tricks we use to analyse systems are useful, but they often make us forget about real-life complexity and how nature works. As Julie sees it, complexity is emergent or unpredictable behaviour. There are always complexities, but Julie underlined the need to adapt despite the unknowns. This, in turn, builds resilience. For instance, nature can be a source of inspiration for innovation to produce sustainable businesses and products.

This process, known as biomimicry, can include directly copying nature, such as using the form of plants to develop a structure that works in harmony with the environment, or co-opting nature, such as integrating plants into buildings to reduce their environmental impact. Biomimicry can help build resilience going forward as nature is always evolving, adaptive, holistic, and zero waste.

Exploiting nature as processes and algorithms

Rupert Soar, Nottingham Trent University

Rupert Soar looked at agent systems based on superorganisms to make the case that we are all part of a system, and part of the solutions, so we need to work together to develop new and better strategies. Like Julie, Rupert provided examples of structures in nature that can be mimicked in construction, such as termite mounds. In nature, resources are scarce, and competition is high so, according to Rupert, as we face more limited resources, we can use knowledge from nature in design that is more efficient, adaptable, and resilient.

Learning from natural systems

Giorgos Masourekkos

Human-centric lighting is a concept that focuses on artificial light mimicking natural light by adjusting the colour temperature of the lights from warm to cold to match the colour temperature variations of the natural light. This is extremely important as people have evolved in a way that these variations are at the heart of our internal clock which is more commonly referred to as circadian rhythm. As most people spend a big percentage of their everyday life indoors, it so follows that providing conditions that are in line with our circadian rhythm impacts behaviour and wellbeing.

Effects of human-centric lighting include:

- Reduced secretion of melatonin during early hours
- Increased levels of melatonin secretion during the afternoon
- Reduction of sleep-inducing drugs

There are many potential applications of human-centric lighting, including in offices and shops.

Dematerialisation

Session chair

Raimund Bleischwitz, University College London

Presentations

1. Dematerialisation and the Circular Economy

   Raimund Bleischwitz, UCL

2. Remanufacturing

   David Fitzsimons, European Remanufacturing Council

3. From Principles to Practices

   Devni Acharya, Arup

Global production systems make logistics difficult: moving to a local system can make things much easier. But, this has implications for business models.

Key insight:

- Cost savings and social impacts make a very good case for a circular economy and dematerialisation – environmental benefits are a bonus.

Summary and recommendations

Many people engage with the circular economy as a guiding principle for design, business activities, and urban sustainability. The long-term aspirations, however, are often less clear. This session focused on dematerialisation – societies using fewer primary resources while enhancing values—from economic growth to more difficult-to-measure benefits such as improved quality of life and reducing environmental pressure. Speakers posed the question of whether these goals are feasible and if they are in line with the UN Sustainable Development Goals (SDGs). These issues form the wider setting for a fresh discussion about a circular economy.

There is a problem with the common rhetoric about the environmental benefits of a circular economy; many people outside of the environmental and circular economy communities are simply not interested and may even be turned away by it. Many stakeholders may only see inconvenience or disadvantages such as perceived increased costs, or a concern that products may be lower quality. To make the case for moving towards a dematerialised system and a circular economy, engineers and designers should emphasise the social and cost-saving benefits as a priority.

One example is in a healthcare service where an electronic registration system can collect and keep data, offering the potential environmental benefit of reduced paper and energy needs associated with storage. However, there is the problem of the potential (or perceived) trade-off against safety and privacy concerns if records are not kept securely. Rather than emphasising the environmental benefits, perception is likely to be better if the provider emphasises the major cost savings, by way of reduced paper use, storage space and operational costs, and social benefits, if patients have better access to their data in a useful and meaningful way that improves service quality. The potential environmental impact of reduced paper and energy needs can be posed as an extra bonus.

Recommendations:

- Build a cost-savings story – there is strong evidence that dematerialisation will save costs – for example, in a case where you move from paper storage of data to digital data you save on the cost of paper and operating expenses.
- Emphasise social benefits – social capital can be improved when people share or have better access to a resource. For example, shared ownership systems can boost social interaction. This principle can be applied to the sharing of experiences or skills.
- Recognise that different stakeholders see costs and benefits very differently. If a 'less is more' mentality is to be adopted, the benefits to different groups must be obvious and outweigh the costs of making the change.

Discussion

In the discussion on dematerialisation, it was generally agreed that a circular economy requires lifecycle thinking and a systems approach to avoid conflicts and optimise the system. This may require a new mindset in business value creation and equitable distributions.

Participants shared challenges they have confronted when designing for a circular economy, which included:

- Data and information about materials and processing
- Justifying initial costs
- Joined up legislation
- Challenging the status quo
- Convincing stakeholders
- Vested interests
- Cultural differences
- Timely policies and regulations
- Time and momentum
- Communicating feedback
- Lack of working examples

To overcome some of these challenges, participants suggested regular communication with stakeholders, bringing in entrepreneurs from different parts of the world, sharing real-life case studies as evidence, more events (such as Frontiers symposia) featuring diverse people to share their experiences, and engagement with other disciplines such as artists, architects, and those working in humanities.

Presentations

Dematerialisation and the circular economy

Raimund Bleischwitz, UCL

Dematerialisation is a mission towards more value creation with fewer resources, in particular, fewer fossil fuels and less throughput of primary base metals and cement. The benefits of wide-scale dematerialisation could include:

- Less environmental pressure
- Planetary boundaries in balance
- More equitable development
- Fairness to future generations
- Adding a larger goal to a circular economy, not only as a method to improve environmental sustainability but also to create social benefits

> "We need new mindsets in business value creation and equitable distribution, alongside policy incentives, and local production and consumption models."

Raimund highlighted trade-offs in dematerialisation, especially in contexts where economic growth is a priority. For instance, progress towards some UN Sustainable Development Goals may trigger additional demand for resources:

SDG Goal 2: Zero Hunger: this could lead to an increase in demand for land, mineral fertilisers, water, biomass and food.

SDG Goal 6: Clean Water and Sanitation: investments in water supply and a water distribution infrastructure could increase demand for materials for construction and impact local freshwater availability.

SDG Goal 7: Affordable and Clean Energy: the implications of increasing demand for bioenergy and renewable energy may require more demand for land, biomass, water, and materials.

SDG Goal 9: Industry, Innovation and Infrastructure: Building new infrastructure could increase demand for energy and materials for construction. Even if green energy is used, it may require increased demand for land, biomass, water, and materials.

SDG Goal 11: Sustainable cities: Growth of cities, even in sustainable ways, has implications for more construction materials, metals, and other resources.

However, circular economy innovation can help balance these trade-offs by:

- Endorsing the sustainable production and consumption agenda
- Calling for global increases in resource efficiency
- Achieve sustainable and resource-efficient infrastructures by 2030 (Goal 9)
- Promoting sustainable management and efficient use of all resources by 2030 (Goal 12).

Raimund concluded his presentation with a list of recommendations to make traction towards dematerialisation across value chains:

- Focus on value creation—socially and environmentally in addition to economically—and establish circular economy dialogues and roadmaps
- Add global scales and material throughputs to circular economy thinking
- Establish mission-oriented policies towards doubling resource productivity while boosting markets for secondary resources, as described by economist Mariana Mazzucato
- Understand the role of commodity prices – introduce resource taxes, sovereign wealth funds and resource dividends to drive change
- Help businesses create transition pathways, but be aware of gaps and establish foresight scenarios
- Work with local organisations and governments
- Turn potential 'losers' (extractives and resource-rich regions) into transition partners.

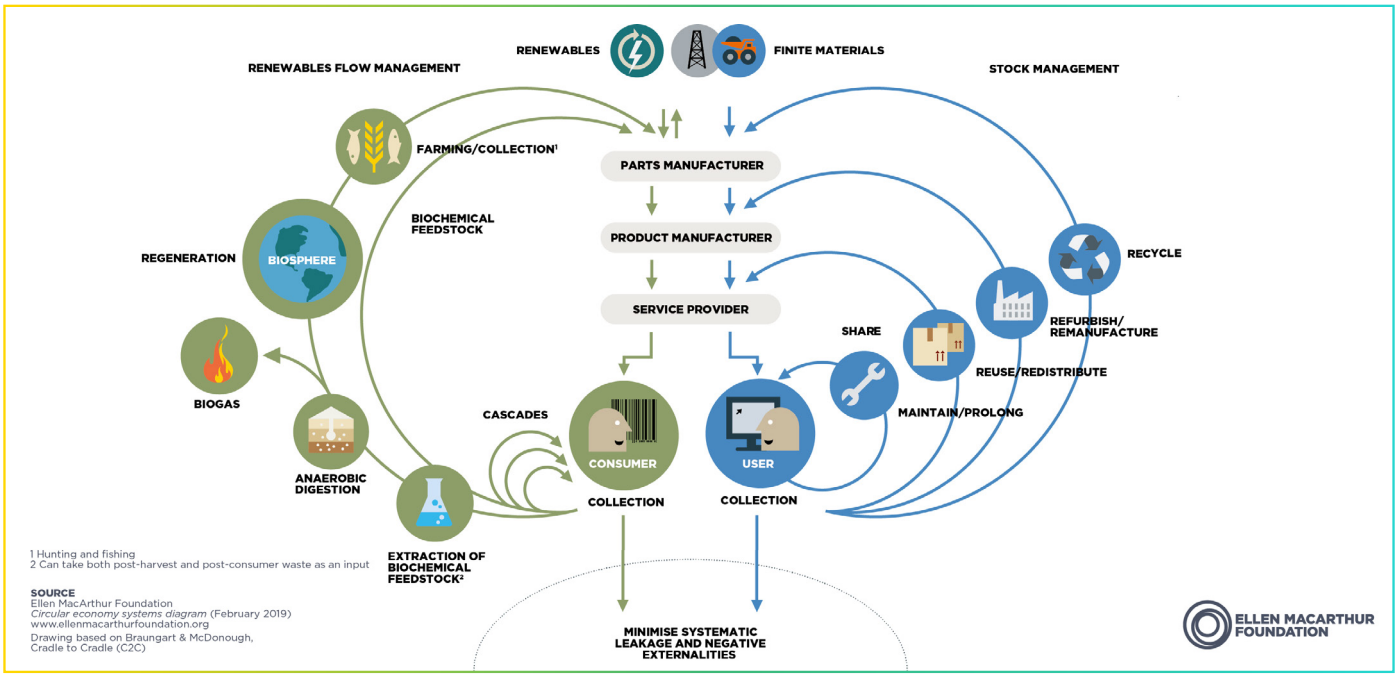
Remanufacturing

David Fitzsimons,
European Remanufacturing Council

Remanufacturing is "returning a product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product."

Taking the example of the dematerialisation of steel, David asked where remanufacturing could fit in to an overall rethink of economic models. Using the WellMet 2050 project, a program that examined the different ways to meet global carbon emissions targets for steel and aluminium across the entire lifecycle of the metals, David identified six strategies to improve maximise products' service:

- **Use less metal for the same service:** making products lightweight can reduce resource needs, but focus on technologies that do not dramatically affect yield, in contrast to subtractive manufacture.
- **Encourage more intense use:** an example of this is bike-sharing, which allows for one bike to be used by many users, as opposed to one bike for each potential user.
- **Focus on life extension:** by ensuring product performance does not diminish and addressing changing user needs through upgrades, users are encouraged to utilise a product for its full lifespan.
- **Divert fabrication scrap:** we can avoid recycling by utilising fabrication scrap in other applications, such as solid bonding of aluminium swarf.
- **Re-use materials:** To avoid recycling, dismantle, clean, test and re-issue materials.
- **Improve fabrication yields:** develop strategic or technological ways to reduce yield loss during the manufacturing process.



From Principles to Practices

Devni Acharya, Arup

Resource and waste

By 2050, the urban population is expected to grow by about 2.5 billion. The growth of the built environment required to accommodate these new inhabitants will drive significant growth in material consumption, for example steel demand is expected to double by 2050, while demand for cement is expected to grow up by 76%.

Most of this growth is likely to take place in Low- and Middle-income countries (LMICs), primarily India, China and Nigeria. They will respond to this growth by building whole new cities and neighbourhoods. The UK faces a different challenge to ensuring cities are environmentally efficient since 87% of existing buildings in the UK will still be standing in 2050. In both contexts, circular economy principles provide a way of ensuring existing materials, buildings and infrastructure are kept in play in the future.

At Arup, Devni's team analysed 116 circular economy projects from around the world to understand key trends and where there is further scope for circular economy implementation. By combining analysis of existing projects and interviews with over 100 stakeholders, they identified the key barriers and opportunities in the transition to a circular economy.

The findings show that the first movers in the transition need to be policymakers, investors, and clients. These three stakeholders are considered "pull" stakeholders. They can influence decisions made at the start of the built environment value chain but also influence decisions made by other stakeholders further down the value chain. They have the greatest control over the business model and contractual framework in which built environment assets are created and operated.

Policymakers

The current focus on embedding a circular economy for policymakers is in national industrial strategies and city strategies. There are some national and regional policy frameworks under development, for example, the European Union Circular Economy Package.

Barriers to implementation:

- Lack of awareness within policy institutions around the systemic nature of a circular economy and its implications or impacts.
- Without a clear supporting national framework, regional policy variations exist making it difficult for stakeholders to operate.

Recommendations:

There is an opportunity for central governments to set clear national policy frameworks that focus on outcomes such as resource productivity, which ultimately sets the industry's direction but allows space for innovation. An additional benefit of having the central government involved is that they have the most influence and power over economic incentives, such as VAT reductions for projects that specify circular economy requirements during procurement. Separate from this, there is also an opportunity to lead by example through circular public procurement.

Investors

Several major investors are looking for circular economy opportunities. For example, ABN Amro constructed Circl, a pavilion built on circular economy principles next to ABN Amro's head office in Amsterdam. They also have a dedicated fund looking to invest in circular economy businesses. However, others are just beginning to understand the need to embrace environmental, social and governance (ESG) considerations in their investment portfolios to mitigate long-term risks, such as resource scarcity.

Barriers:

- Lack of certainty on how circular economy business models might work, from fundamentals like whether the business case makes sense, to how contracts might need to change and how risks might be reprofiled.
- For the construction industry as a player in building with circular economy principles, there is a lack of confidence from investors stemming from long-standing industry fragmentation, low margins and low innovation rates.

Recommendations:

Investors could develop new valuation techniques that consider the whole life cycle costs of assets. Buildings designed to stay at a high value over time, for instance, will depreciate more slowly, thus maintaining value on balance sheets.

Clients

Construction clients are diverse, but from large international construction clients down to small residential developers, there is a common concern around increases in capital expenditures (funds used to acquire, improve, and maintain assets).

Barriers:

- The industry is fragmented with misaligned incentives. The separation of construction and operation makes it difficult to realise the full potential.
- Current contract terms on liability do not lend themselves well to innovation and the adoption of new approaches.

Recommendations:

Collaboration is key. There is a need to bring together all stakeholders to align requirements and incentives to develop innovative projects that can help create a learning loop and inform future policy.

Given their findings, Arup aims to reinforce the message that circular economy is a business strategy, and is not only about sustainability, and this needs to be widely recognised across the built environment to make the transition a reality.

Emma Fromberg

Ellen MacArthur Foundation

In her presentation, Emma explored the role of product design in the transition to a circular economy. There is a trend for more designers, entrepreneurs, and other makers to consider circular design principles in their work, and integrate circular economy principles into their businesses. As more of these so-called 'circular' products are being put on the market, questions arise about what the impact may be on society and the environment. She challenged participants to question what happens when a business model changes from selling products to selling services, or what kind of 'sharing' really happens on sharing initiative platforms. This highlighted the importance of considering the wider impacts, be they economic, social or environmental, and fully exploring the perspectives of multiple stakeholders.

Carol Lemmens

Arup

Carol leads Arup's Global Advisory Services business and spearheads Arup's circular economy work. He was instrumental in developing Arup's position paper to define the circular economy in the context of the built environment, and coordinates Arup's work as the Ellen MacArthur Foundation's (EMF) knowledge partner for the built environment.

In his presentation, he discussed the partnership that enables the Foundation and Arup to work together to develop circular economy principles across cities, transport, energy and water projects. Carol also described a new collaborative research project to scope a circular economy visions for cities around the world as part of the Circular Cities research project.

Royal Academy of Engineering

For more information, including eligibility,
please visit **raeng.org.uk/frontiers** and follow **@RAEngGlobal**

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