Circular Economy – Future Landscape

26th July 2018

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Introduction

A circular economy is one where products and materials are kept at their highest value for as long as possible. This requires processes, technologies and whole systems that allow the reuse, repair, recycling and retrieval of products and materials. This would create productivity, secure resources, prevent environmental damage and minimise waste.

EPSRC wanted to engage with a cross section of the circular economy community in order to establish a perspective on where engineering and physical sciences contribute to the circular economy and how best to deliver support to the area.

On the 26 July 2018, EPSRC held a one-day workshop at the Holiday Inn, Bristol, in order to bring together a range of technical experts to discuss research challenges and requirements. The results of the workshop, comprising this report and the notes taken during the day will be used to assist the EPSRC to understand Circular Economy from an Engineering and Physical Sciences context, the underlying research challenges and the direction EPSRC support should take to address these challenges.

Aims and Objectives

The objectives of the workshop were:

- To identify what Engineering and Physical Sciences research is required to enable the circular economy
- To consider which areas the UK can address competitively
- To discuss how to support the research landscape to ensure impact

Attendance

Due to time constraints we were unable to invite expressions of interest to attend the workshop through an open call; instead attendees were invited based on their knowledge and experience, with the intention of achieving a balance of academic disciplines. Delegates were selected from EPSRC grant holders who are active in the area of circular economy. A delegate list is provided in Annex 1

Workshop Outputs

An introductory presentation was provided to highlight the purpose of the day. Following this the delegates were led through a series of exercises in small groups with time made for plenary discussions.

Session 1 – What Research is required to enable a Circular Economy

The key aim of this session was to consider what the key challenges in enabling the circular economy are. The delegates were provided with three key features of the Circular Economy as identified by the Ellen MacArthur Foundation:

- Materials kept in use and waste minimised
- Products kept in use
- Natural resource utilised in a restorative and regenerative manner

They were asked to consider what is required to enable these features and then to consider what are the current barriers to the enablers identified. The delegates were asked to consider all aspects of the circular economy at this stage, regardless of whether the enabler or barrier was relevant to engineering and physical sciences.

The enablers and the subsequent barriers for being able to **keep a product in use** where identified as:

- The ability to design products for use with in a circular economy
    - Barriers: included knowledge of materials properties being available for designers including information of the ability to recycle the material; The need for trade-offs between various cycles e.g. the performance during use vs. ability to maintain; the need for the designer to be aware of how the product will be utilised, e.g. which business model will be used.
- The ability to maintain, repair, remanufacture and repurpose products
    - Barriers: The lack of appropriate infrastructure for returning products; The lack of available knowledge of material properties; The consumer need for the use of the product at all times so not available to 'pause' the service to allow for maintenance – this is especially key in industries such as transport or healthcare
- Modular design
    - Barriers: The ability to design for future technologies, the economics of how to provide modular products; Customer awareness and acceptance of upgrading rather than purchasing a new product; the price of primary materials;
- Systems knowledge to ensure the best product lifestyle decision is being under taken, e.g. How many times can a product be maintained before remanufacture or repurpose to ensure it performs at the highest possible level.
    - Barriers: The amount of knowledge and information required to fully calculate such decisions; the time and cost of performing the calculations; the business awareness of the potential lifecycles.
- Service based business models (rather than product ownership)
    - Barriers: Consumer acceptance of not owning products, The lack of value for consumers in returning products and the inconvenience they may perceive; Consumers may perceive purchasing the service as more expensive; The population growth means that more products will be required
- Legislation
    - Barriers: Public Awareness of the Circular Economy; Political motivation

The enablers and subsequent barriers for being able to **keep materials in use and waste minimised** where identified as:

- Material simplification at the molecular level
    - Barriers: The trade-off between functionality and recyclability; The need for identified uses and markets for recycled material; the waste industry currently requires waste
- A 'Magic Sorting Machine', which can identify and sort any material by its molecular make-up. This could also be extended to a machine that could sort and begin the recycling/reprocessing process.
    - Barriers: The need for robotic disassembly; The rate of material discovery and product invention; Sensor ability;
- Recovery and Collection of Materials

    - Barriers: Consumers perceive returning material as inconvenient; Consumer doesn't benefit from the return of the material.
- Valorisation of Secondary Materials
    - Barriers: Standard metrics and indicators; Energy requirement of recycling is linked to the cost of the material; a lack of incentive for their utilisation;
- A restricted supply of a resource has the potential as a driver for innovation, e.g. by making secondary material cost beneficial
    - Timescale of the innovation
- Connected supply chains; a detailed understanding of what supply chains are available and the best on to use is required
    - Barriers: information on supply chains and which industries require what supplies; cross sector interaction;

The enablers and subsequent barriers for being able to **utilise natural resources in a restorative and regenerative manner** where identified as:

- Limit extraction and ensure efficient extraction of resource (maximum amount of usable product from the natural resource)
    - Demand from consumers; relative cost of full utilisation of a resource versus further extraction;
- Utilisation of biological alternatives (to mineral products)
    - Barriers: Functionality of the new materials; Ability to return bio-based materials to the biocycle;
- Secondary mining (extraction of resources from products or waste products from traditional extraction)
    - Barriers: Relative cost compared to primary resources; Ability to extract resources from products, e.g. ability to disassemble products;
- Consideration of the global value chain to allow products to be utilised or valorised at the most sustainable point in the chain
    - Barriers: Limited knowledge of global value network design
- Use of secondary resources to help stabilise primary materials markets
    - Barriers: complexity of global markets; Ability to move resources globally

The plenary discussion highlighted the need for detailed systems analysis in all cases to understand what would be the best route forward for any material or product at each stage of its lifecycle. There was also a defined need for multidisciplinary research.

Session 2 – What Engineering and Physical Science research is required to enable a Circular Economy

The second session of the day focused on narrowing down the barriers from session 1 to more specific engineering and physical science challenges. The barriers identified in session 1 where clustered and 17 areas with an engineering and physical sciences focused where taken forward. The delegates were asked to consider for each item identified, what are the barriers to this item and what would enable this barrier to be overcome.

The results are shown below:

Item	**Barriers**	**Enablers**
Sensors for Recycling	Mixed waste systems	
	Ability to sense quality as well as material	
	Non-Surface techniques	
	Sensing of new and future materials	
Separation Technologies	Cost of separation	Automation, Markets for recycled materials; Changing attitudes to 'not new' products; material choice by property rather than make-up
	Ability to detect quality as well as material	
	Ability to sense all materials in a multiple material product	
	Ability to separate	Technologies that retain the value of products as well; Pre-recycling sensing to determine need for recycling
	Ownership of material	Leasing of materials rather than Sale
Waste Valorisation	Contamination/ toxicity	Metrics and indicators
	Collection and separation Costs	
	Biological and chemical techniques are competitive	
	Volume of available products	Better extraction techniques; Robust catalytic conversion processes to deal with entropy and mixed feedstocks
	Legislation	Impact fellows to work with government to adapt/create legislation
Remanufacturing Technologies	Molecular disassembly of materials and products not yet possible	Technology to detect/inform what is being remanufactured and the current quality
	Lack of market for remanufactured goods	Public engagements, legislator, material selection by property not make up
	Cost and lead time of remanufacturing technology development	Robots that can handle extreme variety and uncertainty; Design in the ability to be remanufactured
	Guaranteeing material integrity	Diagnostics, analysis, imaging and quality control
Repair Technologies	Ability to repair	Self-healing materials; Products designed for repair; Repair locations distributed to ensure convenience; Ability to upgrade and repair at the same time
	Consumer behaviour	Education; Legislation; Information provided on reparability, intended lifetime etc.

Item	Barriers	Enablers
	Equipment for repair process	Robotics; on site manufacturing of parts
Disassembly	Products aren't designed to be disassembled	Design for disassembly across all length scales; process that can cope with a range of products; Organisations to disassemble their own products; Additive manufacture for parts for repair
	Cost focus in design	Education of consumers to expect things to last; Through life costing; lease models
	Method of disassembly may depend on the reason	Better valorisation of materials, Homocomposite materials, Energy efficient molecular disassembly; Robotics; Use of AI and vision systems.
	Energy cost	Cheap renewable energy
	Products need to stay assembled until disassembly required	
Modular Design	In competition with new products	
	Additional cost	Standardise parts; Simplification of design
	How to incentivise	Producer to retain ownership; Decision making of when to renew part or whole product
	May compromise performance	Easy disassembly – appropriate for type of product; Avoid need for modularity by simplification of design
	Location of product and ease of extraction	
Whole System design	Defining the limits of the system	Developing designers with whole system design skills; Network definition and analysis
	Tools to assess at the system level and disseminate information to key stakeholders	Collaborative system design with stakeholders and development of assessment tools; Design of products and the business models at the same time
	Disconnection between the different elements of the system	
	Getting the right stakeholders to engage to deliver the right solutions	Consideration of ownership and responsibility issues
Circularity Metrics	Defining what we need to measure	Discussion needs to be government led;
	Danger of de-coupling from sustainability	Responsible consumerism needs to be considered within the circular economy
	Metrics may inhibit transitional technologies	
	Standardisation across multiple industries	Development of common framework/language
Tools for Complex Analysis	Need to know what to measure before creating tools	Use of big data to influence/inform User trends and behaviours; Algorithms and machine learning to inform when to consider

Item	Barriers	Enablers
		each process; use of government targets to define metrics; Stakeholder engagement to identify/select indicators and metrics
	Collection of the correct data	Definition of what data is needed; Approaches developed to deal with data difficulties in decision making
	Access to the data to enable circular design	Creation of open-access data repositories
	Integration of the circular and digital economy	support systems designed to understand trade-offs in decision making
	Need to quantify and tension diverse factors	Heterogeneous Network Analysis
Supply Chain and Infra structure	Appropriate capture and transfer of waste resource s	Inventory systems for materials; Supply chain design considered at the beginning of the process; Materials research to include end of life consideration of the material
	Location of the user of secondary material	Develop necessary recycling infrastructure in the correct geographic locations; Network modelling of critical waste streams
	Infrastructure not present	Invest in suitable infrastructure
	Supply chains are global	Global value network design; decision making of where is the best location to add value to a material/product
	Home deliveries often a key part of CE business models but can be inefficient and not always consumer preference	Consolidated delivery; Pickup combined with deliver; Incentives for returning things.
Extracting Material	New Separation Technologies	Consideration of level of separation is important (Physical; robotic; chemical; biological; pyrometallurgy)
	Products contain multiple materials	Development of separation technologies
	Cost of material Separation	
	Robotic Disassembly	
Biobased Alternatives	Need to be competitive with traditional material	Education of designers/companies on what is available
	Economy of scale not present	Focus on unique qualities of bio-bases materials rather than as a like for like replacement of fossil fuel derived materials; Utilise cascading supply chains that optimise value during the use-phase and then return organic matter to the land
	Competition of feedstock with food	Use non-edible feedstocks; use food-waste; Selective benign catalysts for biomass conversion
	Understanding of natural construction systems (e.g. spider webs)	Collaboration across disciplines
	Appropriate feedstocks	Use of Industrial Biotech solutions to generate feedstocks

Item	Barriers	Enablers
Materials Processing	Identify materials of the future	
	Identification of high potential existing material streams	
	Maintaining quality of materials through the cycles of a circular economy	
	End of life considerations not developed for new/future materials	
Process Intensity	Scalability of processes	
	Current chemical process not appropriate for the circular economy	
	Separation technologies	Waste based catalysts
	Cost of advanced processes	
Material Tracking	Long Supply Chains	Blockchain
	Lack of Information	AI, Big data techniques,
	Knowing what amounts of material to track	Identity 'chips' embedded in the material;
Product Tracking	Effective labelling and sensing systems	
	Sharing of data between stakeholders	Identify what data needs to be captured
	Security of information	IT security related to internet of things

Session 3 – Assessment of Research Challenges

The focus of this session was on considering to what extent the areas discussed in the initial sessions were underpinning for the circular economy and whether the UK had a leading edge in any of the areas. For each area, a discussion was had on the following:

- How good is the UK at research in this area
- How much research is happening in the UK in this area
- How good is the rest of the world at research in this area
- How important is this area to achieving impact in the circular economy
- How much excitement is there relating to this area (general public, government, Industry)

Due to the select number of delegates present it was not felt that a rigorous answer to these questions could be presented externally.

In general the discussion focused on the following points:

- The UK often has significant capacity and capability in areas relevant to the circular economy, but does not always have expertise in all aspects of the areas identified. It was also noted that while the expertise may be present, there are several instances where it is not yet being applied to the circular economy.

- There is significant and growing activity occurring worldwide related to the circular economy and the UK will be left behind if research into the circular economy is not supported.
- The levels of excitement of an area depends largely on how aware the different sectors are and that more engagement and education will be necessary to ensure impact from the circular economy.

Session 4 – Supporting the Research Landscape

The focus of this session was on other ways (than direct funding) that the research landscape required support to ensure impact. Impact was defined as the required technologies and systems knowledge being available to implement the circular economy.

The key points raised in this session where:

- A multidisciplinary approach is required. All disciplines need to be connected to achieve impact. All projects will need buy-in from multiple parties, including outside of academia, if they are to be successful.
- A joined up approach to strategy and funding across UKRI was noted as an important driver for the area. The need for cross council funding was identified.
- Systems analysis is the underpinning understanding that is required to allow effective impact. The identification of intervention points will be key in solving problems, and communicating to stakeholders such as policymakers and industry.
- The UK community, of all disciplines, needs to be brought together. Suggested approaches included having a physical or virtual centre. One key role of this centre could be to perform a road mapping exercise to identify key areas and people.
- There needs to be a forward looking approach, to ensure that future problems are solved as they arise. The ideal was described as the embedding of circular approaches as materials and products were invented rather than as a secondary consideration.
- There is a need for agile and flexible projects to tackle challenges as they arise and allow the testing of creative high risk ideas.
- All stakeholders need to be involved in the research. This includes the public and policymakers as well as Industry. The importance of SME's was also identified, along with the difficulties of encaging with them that needs to be overcome.
- There is a need for demonstrators in university settings to enable impact.
- There is a need for skilled researchers who have a multidisciplinary background. It was suggested that more relevant PhD training is required. Increased support for researchers was also described as key, especially between projects in order to help retain skilled researchers. The diversity of researchers needs to be improved. researchers with less traditional backgrounds or people carrying out less fundamental research, e.g. technology innovators, need to have their career paths recognised and supported

Conclusion

The workshop proved to be a successful event and a large volume of information was generated on the day. It was important to see the cross-cutting themes that emerged from the initial sessions and the clear points raised regarding the research landscape, these will be used to help develop future EPSRC strategy and activity.

There was a strong sense that the circular economy is a multidisciplinary challenge that crosses the entirety of the UKRI remit but that engineering and physical sciences will play a key role in enabling the circular economy. It was also noted that there is a need for systems analysis to be embedded in all aspect of the circular economy.

The need for training, support of researchers and the accreditation of impact activities was raised and the workshop gave the impression that more could be done in these areas. Regarding training it was clear that there is a need for researchers who have multidisciplinary skills.

Overall EPSRC has a vital role to play in the Circular Economy but for true impact to be achieved, a truly cross UKRI action is needed.

Annex

1. Delegates

Fiona	Charnley	Cranfield University
Matt	Davidson	University of Bath
Jan	Godsell	University of Warwick
Sven	Herrmann	Ellen Macarthur Foundation
Winifred	Ijomah	University of Strathclyde
Jacquetta	Lee	University of Surrey
Anne	Velenturf	University of Exeter
Allan	Walton	University of Birmingham
Chick	Wilson	University of Bath

2. Agenda

10.00 Welcome and Introduction

10.30 Session 1 – Identifying Research Challenges in the Circular Economy, Part 1

11.40 Refreshments

12.00 Session 2 – Identifying Research Challenges in the Circular Economy, Part 2

13.00 Lunch

14.00 Session 3 – Assessment of Research Challenges

14.45 Refreshments

15.15 Session 4 – Supporting the research landscape

16.00 Closing Remarks

16.15 End