European Commission

ERA
Industrial technology roadmap **for circular technologies and business models**

in the textile, construction and energy-intensive industries

ANNEXES

Research and Innovation

Annexes: ERA industrial technology roadmap for circular technologies and business models in the textile, construction and energy-intensive industries

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Manuscript completed in December 2022
1st edition

PDF	ISBN 978-92-76-57695-2	doi:10.2777/447000	KI-04-22-112-EN-N

Luxembourg: Publications Office of the European Union, 2023

EUROPEAN COMMISSION

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in the textile, construction and energy-intensive industries

Annexes

Prepared by Technopolis Group, for the consortium

2023 Directorate-General for Research and Innovation

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ANNEX 1 | METHODOLOGY OF TECHNOLOGY ASSESSMENT

The assessment of circular industrial technologies was based on a methodology following a combination of qualitative analytical steps and foresight exercise:

1. **Technology scoping**: The first step of the analysis consisted of a comprehensive desk research complemented with interviews with industry stakeholders, which allowed to map a wide set of technologies and techniques that address material efficiency, waste- and side stream recycling, reuse and waste reduction as part of the circular economy objectives. Such technologies were identified for each industrial ecosystem and for each life-cycle stage of the industrial production starting from material sourcing, preparation, processing, manufacturing, and end of life. This scoping exercise resulted in three lists of technologies (consisting of up to 25+ technologies per industrial ecosystem) that were discussed and validated at a dedicated focus group meeting with 40 participants from industry, research and technology organisations, academia and the European Commission services including the Joint Research Centre.

2. **Development of technology assessment criteria**: Identifying the maturity level of each technology, notably their Technology Readiness Levels (TRL) was the next step of the analysis. In order to assess the potential contribution of technologies to the circular economy, a set of assessment criteria has been selected in consultation with industry and research stakeholders at the focus group meeting mentioned above. These criteria included the following:

    - *Circularity potential* has been defined depending on three following main models such as 1) Waste minimisation (e.g. via recycling possibilities for end of life of products or side-streams); 2) Resource saving (efficiency), e.g. materials, water, fuel, energy; and 3) Longer life span of products/materials (due to better repairability, higher durability, modularity)

    - *Economic potential* has meant the assessment of the overall cost-efficiency, market feasibility, payback time, economic savings that the technologies can offer

    - *Contribution to zero-pollution* meant the assessment how far the circular technology can reduce water, air, soil and other pollutions.

    - *Risk of possibilities for negative/rebound effects* can arise while implementing the technology or technique including negative environmental side effects. The use of the technology can in certain cases reduce the expected gains because of creating new increased consumption or other negative behavioural responses.

3. **Technology assessment process** has been framed around the above-mentioned assessment criteria which were applied in the analysis of each technology groups scoped. The results of the technology assessment highlight the main technology groups relevant for the circular transition of each industry and serves the purpose to identify overall potential. There is a lot of variety in the maturity level of each individual technology within the broader groups that

has to be accounted for. Evidence has been collected through a mix of methods:

- Desk research included the review of academic and technical studies about specific technologies, research and innovation strategies of European Partnerships, extracting relevant information from European research and development projects, and other documents that have research, innovation, environmental and economic performance analysis of technologies.

- Interviews were conducted with industry representatives, technology developers and researchers who had information about the selected technologies and developments in the targeted industrial ecosystems.

- Delphi study included a group of selected experts and practitioners from the textile, construction, chemicals, steel/metal and ceramic industries, and researchers involved in the R&I of these technologies. Experts have been identified for each industry who had been invited to participate in the Delphi survey conducted online. Two rounds were run anonymously and gathered expert opinion on each technology assessment criteria and for each technology. According to the methodology, the participants could see the results of the first round of the survey and identify how much their response diverges or conforms the overall group result, as well as read the comments provided by other experts participating in the Delphi. In the second round the experts were invited to revise their responses in order to bring them closer to consensus. It has to be noted that very big convergence was not reached in all questions, while not all could provide answers on each criterion or on each technology.

4. **Final validation workshop**: A validation workshop with industry representatives was organised on the 31 May and 1 June 2022 with the objective to validate the choice and assessment of technologies identified as essential in the transformation of industries towards a circular economy in the EU, discuss the role of business models, organisational and service innovation, and identify barriers and enabling framework conditions to put circular industrial technologies on the market and reach wide diffusion.

5. **Public consultation**: A public consultation was conducted between August-October 2022 with the objective to gathering further opinion and validation from a broader group of stakeholders.

All these steps in the evidence collection and the related methods have complemented each other and allowed to get a good overview about the circular technologies' potential. Nevertheless, the analysis also revealed that there are still a lot of unknowns and uncertainties about the future application of circular technologies.

Definitions of technologies:

For the purposes of this report, circular industrial technologies have been defined as a collection of various knowledge applications that enable the reduction or avoidance of waste, foster recycling, reuse, remanufacturing, repair, industrial symbiosis, redesign for better circularity and shared use (e.g., IT solution for product sharing, rental). For the purposes of this roadmap, the identification of technologies remained broad and have a lot of diversity hidden within the categories presented. To realise an effective positive change, it is not only technologies that matter but how technologies are coupled with new organisational and business models, services and systems that can ensure a system-level transformation. Further technology definitions include the following:

Material technologies that focus on the development of advanced sustainable materials can lead to circular and higher value-added products, but also to new reduced cost substitutes to existing materials. Material technologies can facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials.

Clean production technologies encompass the use of innovative technologies to improve products or processes that drive innovation and can help put in place circular manufacturing processes.

Recycling technologies enable the process of converting waste materials into new materials and industrial products. They can address side-streams in the earlier stages of the lifecycle, e.g. recycling of waste water in order to re-feed it into production, or recycling of waste streams to extract valuable materials and re-introduce them into value chain.

Digital technologies are instrumental to support the circular economy. This category includes among others artificial intelligence, big data, augmented and virtual reality, blockchain but also other basic digital technologies such as ICT to create web platforms that can facilitate resale and recycling. Digital technologies can help both in monitoring and optimising the existing processes, resource use, waste minimisation, but also in providing new solution like 3D printing in construction, or introduction of digital product passport to improve transparency about products/materials, facilitate recycling, etc.

Cross-cutting approaches:

Industrial symbiosis – is a cross-cutting approach that includes technological solutions that facilitates waste-to-value principles, diverts waste from landfilling and promotes waste/resource exchange-based collaborations among industrial facilities. Industrial symbiosis has a potential in most/all industries and reply on technologies for monitoring and valorisation of side-streams, recycling and resource efficiency.

Resource and energy efficiency measures – are incremental improvements but can offer big saving and waste minimisation potential in every industry. Often, they are seen as low-hanging fruit in reaching reducing material/water/energy consumption and contribute to circularity and sustainability objectives

Design for circularity is also a cross-cutting approach that can help to transform industries and make them more or fully circular. Design of products, materials, processes should integrate possibility for more efficient and easier recycling, remanufacturing, reuse, repair or extend durability.

ANNEX 2 | TABLES OF CIRCULAR INDUSTRIAL TECHNOLOGIES

This annex lists circular industrial technologies identified for the purposes of this roadmap.

Textile ecosystem

Table 1: Textile technologies

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
Environmental impacts of the textiles industry are manyfold and include pollution from the production of fibres, the manufacturing of textiles products to environmental burden created in the form of waste at the end of the lifecycle. In addition, fast fashion trends have created mass-production of short-lifecycle clothing (in addition to excessive consumption and waste).	Changing current design practices in a way that the fabric and product is composed of sustainable properties and can be easily transformed into fibre and new products again without any loss in quality.	Design for sustainability	Design of textile materials with more sustainable properties	**Design of sustainable materials** can mean the use of materials that are either biodegradable or do not shed microfibers, and which have properties needed for high-performance applications.
			Design for extending garment life	**Design for extending garment life** is a key opportunity to reduce consumption and therefore avoid the carbon, water and waste footprint associated with production. This can include ensuring high quality fabrics when designing garments; designing garments that are multi-functional; facilitating alterations through adjustable waistbands, generous seams or additional buttons. It can also mean the selection of materials and components that

				can withstand the chemicals used in the dry-cleaning process.[10]
			Design for disassembly Mono materials for textiles	**Design for disassembly** is a design principle that takes into account the end-of-life options of how the product, components and materials can be deconstructed at the end of the product lifecycle. When designing textile products in a sustainable way, designers need to avoid textile blends in order to facilitate recycling at the end of the product lifecycle.
			Fabric optimisation at the garment design stage	**Fabric optimisation at the garment design stage** can be supported through the use of pattern and marker making software. Software programmes such as Optitex Digitiser allow the designer to visualise their design on a 3D view, which is simultaneously displayed.
		Materials technologies	Fabrication of fibres from secondary bio-based raw materials (e.g, agriculture and forestry waste)	**Bio-based materials**: Recent R&D in biotechnology allows new technological innovations for producing fibres and textile from the

				residuals of agriculture. For example, waste streams from rice, maize, bananas, pineapples and sugar cane can be used as raw materials for clothing fibres (WUR, 2021), or oilseed hemp/flax, CBD hemp (e.g. by Agraloop[5] and other examples [6]).
			Replacement of raw materials with recycled materials	Yarn production can be replaced by **regeneration of used materials** into yarn for new textile is the transformation of old garments into new raw material. Regenerated yarns can be used to produce fashion garments with considerable economic and ecological advantages. This is achieved through the significant reduction of the consumption of water, pesticides and chemical products normally used during production.[15]
At the yarn to textiles and production stage, the biggest environmental impact of the industry is associated with high water intensity coupled with high water pollution (e.g.	In order to reduce the resource use during the textiles manufacturing stage, practices in production methods and techniques need to be changed.	Clean production technologies	Circular dyeing processes: water efficient and water-free textile/yarn dying technologies	**Water efficient and water-free dying technologies** address one of the biggest dual negative impacts of textile production notably water pollution and water consumption. Most dyes escape during conventional wastewater treatment

during dyeing) and pollution from the use of chemicals. Production of cellulose-based fibres requires a large amount of chemicals. The production of cotton accounts for 16% of all pesticides, 4% of nitrogen and phosphorus fertilisers. Heavy chemical use is involved in making cellulose-based fibres (in particular viscose) and of plastic-based fibres, as well as releases of greenhouse gas and water pollution.				processes and persist in the environment causing negative impact. An example of such technology is a pre-treatment of yarn that modifies its chemical structure to make it more receptive to dye without the discharge of hazardous substances. There are other circular technologies that do not use any water but instead compressed carbon dioxide as a solvent in the dyeing process (eg. developed by DELFT University and DyeCoo).
			Electrochemical pigment colouring	**Electrochemical pigment colouring** helps creating colour properties with higher efficiency and lower energy and chemical consumption than traditional methods.
			Recycling of the dye in the wastewater of textile dyeing processes for further reuse	Emerging circular technology in dying process focuses on **encapsulation of the dye in the wastewater of textile dyeing processes for further reuse**. For example, the DYE4EVE project[7] proposed using natural element, cyclodextrins molecules (traditionally applied into pharmaceuticals and cosmetics) for

				encapsulating the unfixed dyes instead of chemicals that destroy dyes. Cyclodextrins based method allow both, reuse of the recovered dyes and reuse of water.
			Plasma technologies	**Plasma surface treatment of textiles** allows various finishing treatments to enhance textiles properties (reaction to water, dye absorption, anti-pilling, etc.) without the use of hazardous chemicals or affecting a garment beyond its upper layer.
			Reducing water and chemical needs with ozone technologies	**Ozone treatments** allow for a reduced use of chemicals and water in textile finishing processes (dyeing effects).
			Digital micro-factories (digital print, cut, sew)	**Digital micro-factories** have the potential to reduce overproduction with the help of digital printing, cut and sew technologies. A high level of standardisation in the clothing produced can be maintained and 20 % of fabric leftovers diverted. This can be done by adapting processes slightly by use of leftover materials in

				invisible parts like pockets, cuffs, visible, but smaller parts, and designing garment with special waste stream in mind. [8]
			Cleaning, repairing, reconditioning	**Technologies that enable cost and resource-efficient cleaning, repairing, reconditioning** can have a significant impact on overall cradle-to-cradle environmental footprints and reduce pollution and waste generation by extending product lifetime or enable reuse.
A large part of post-consumption textiles ends up in landfill. Fast fashion has resulted in even higher textile waste volumes. Current production practices make recycling complicated and costly, due to a lack of efficient processes to re-process blends of fibres (especially when mixing artificial and natural fibres). In landfills, the substances of concern that are contained in the textiles (dyes or chemicals) can leak out into the environment during	Closing the loop at the end of the lifecycle is critical that starts with an effective sorting, the separation of materials and with the establishment of recycling mechanisms across the whole industrial ecosystem. Recyclability is closely linked to circular design.	Sorting	Automated fibre sorting technologies (near infrared)	**Automated sorting technologies** revolutionise textile-to-textile recycling and help turning waste into new products. Near infrared technologies for automated fibre sorting are used to identify and quantify cotton and polyester and to detect fibre processing. For these technologies accurate sorting based on composition and colour is a key enabler for achieving higher quality products. Research and implementation of hardware and other non-compatible trim removal such as labels is still to be developed (e.g. Fibersorts project https://www.fibersor

degradation. E.g It was estimates that the degradation of textiles in landfills accounts for the release of over 2,000 tonnes of hazardous colourants in the EU each year[1].				t.eu/).
		Separation	Material blend separation technologies	Technologies exist **to separate material blends** as part of the recycling process, although separate steps are required, and the processes are only feasible for materials that are used in large enough quantities in the input material. Technologies at pilot scale exist for blends of polyester and cotton or other cellulose-based materials. Materials that are produced in very low quantities, such as elastane, can be part of the input to those processes but are lost as leftover sludge. **Material blend separation of biodegradable and non-biodegradable fibres** is very challenging and at the moment solutions for recycling are close to non-existence. Alternative solutions that look more promising are about substitution of non-biodegradable components with biodegradable. Besides fibres,

[1] https://www.circularonline.co.uk/wp-content/uploads/2017/11/A-New-Textiles-Economy_Full-Report.pdf

				these can also concern labels, stitching, dyes, buttons.
		Recycling technologies	Post-consumer recycling by adding cellulose-based fibres Regeneration of used textile materials into yarn Chemical recycling: textiles polymers into new polyester products/cellulosic waste of cotton to viscose or lyocell	**Recycling technologies** consist of mechanical, chemical and thermal processes. Chemical recycling technologies have the potential to process post-consumer textile, particular blended materials (and other cellulose materials/waste like paper and pulp) and address mechanical recycling limitations such as loss of fibre length.
Textile production processes, consumption patterns and use are not optimised resulting in an extra waste, loss of materials and creating additional environmental burden. Moreover, information about the properties of textiles products is often unreliable, due to value chains being global and very fragmented with a lack of accountability.	The better collection of information along the value chain of textiles production and exploitation of data with the support of various digital technologies can reduce waste and pollution.	Digital technologies	Digital technologies to facilitate collaborative consumption business models	**Digital collaborative consumption** models include for instance rental, reuse (second-hand clothing) and other servitisation business models (repair services) that are enabled by an online platform and the use of digital technologies. Clothing rental subscription models have been emerging for various types of clothing (fashion clothing[11], sport clothing[12], baby clothing[13].
			Artificial intelligence used for optimisation	**Artificial intelligence (AI) technologies** have been defined as a

			and analysis	“set of technologies able to identify complex structures from massive datasets and to use these structures to make predictions and/or take actions and decisions on previously unseen data”2. AI can be used to predict the properties of the fabric and materials based on fibre, yarn, and fabric constructional data. AI can be also useful to investigate the quality properties before selecting a material and help make more environmentally friendly decisions.
			Digital authentication/passport for textile products and materials	**Digital authentication/passport** allows the monitoring of textiles production and use and fostering conscious purchase and consumption models, recycling, and reuse. Easy access to product content and other information can optimise take-back, recycling, refurbishment and authentication of goods (e.g. branded goods) for second-hand marketplaces.
			Digital technologies for tailored product	**Digital technologies with augmented and**

[2] Baptiste Caramiaux, Fabien Lotte, Joost Geurts, Giuseppe Amato, Malte Behrmann, et al.. AI in the media and creative industries. [Research Report] New European Media (NEM). 2019, pp.1-35.

			selection via augmented and virtual reality	**virtual reality** are expected to reduce the impacts of the increasing package returns by customers. These can give consumers the possibility to experience clothes online. This way, consumers will only order the items they are sure about and that fit well, which reduces the number of packages being sent and returned.

Construction ecosystem

Table 2: Construction

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
Design	The construction industry generates a high volume of landfilled waste, due to, amongst others, a lack of effective circular design practices and tools.	Deploy technologies that enhance sustainable design. Mainstream (more) circular design practices and the required tools, while safeguarding incompatibility and the development of shared standards (see below).	Building-Information-Modelling-Compatible (BIM-compatible) plug-ins and applications / 4D BIM	Building Information Modelling (BIM) is the digital representation of a built assets, containing relevant information such as the building's geometry, material properties, and quantities of elements. More complex, managerial applications of BIM may include / enable what-if scenarios and analysis of alternative solutions considering costs, energy performance and disruption to

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
				users. 4D Building Information Modelling (BIM) is the process of using 3D models, combined with time and schedule-related information to create a virtual construction sequence.
			Modular design Design for disassembly	Structural and building elements are compiled and constructed in a manner that allows for modular assembly, where each module can be removed and reused later in its product life. Design for disassembly is the design of buildings to facilitate future changes and dismantlement (in part or whole) for recovery of systems, components and materials, thus ensuring the building can be recycled as efficiently as possible at the end of its lifespan.
Raw material sourcing	Sourcing raw materials that are either recycled or fit for recycling is a difficult feat as	Streamline sourcing processes and make them more efficient by creating suitable	Urban Mining	Urban mining comprises "the activities and processes of recovering materials and

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
	the corresponding infrastructure as well as a coherent and binding legislative framework that creates standards for those recycled materials are absent.	and enabling framework conditions.		elements from used buildings, infrastructure, or waste, perceiving the building stock as a unified system that serves as a material repository, and waste (irrespective of its source) as an intermediate state through which something new can emerge" (Kakkos, et al., 2020).
Production	The production process using circular materials currently tends to be time- and cost-intensive, and is oftentimes only economically viable at larger scale.	Deploy technologies that enhance sustainable production practices.	Additive / Robotic Manufacturing	Additive Manufacturing (AM) is a manufacturing technology that enables the fabrication of complex 3D objects by adding materials together layer upon layer. Examples include concrete printing as well as the fabrication of components from metals and polymers. Robotic Manufacturing (RM) is a manufacturing technology that enables robots to do part of the work previously done by humans, especially repetitive, dangerous, or precision-requiring tasks, such as assembly, lifting,

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
				or welding.
			Off-site construction	Offsite construction refers to the manufacturing, planning, design, fabrication, and assembly of building elements at a location other than their final installed location to support the rapid speed of, and efficient construction of a permanent structure. Such building elements may be prefabricated offsite in a different location and transported to the site or prefabricated on the construction site and then transported to their final location.
Deconstruction	Technologies employed during the deconstruction phase need to recycle materials that have been used for buildings and infrastructure that had been designed according to non-circular principles.	Improve deconstruction processes to ensure that waste can be recovered	Heating air classification System	Designed to further expose the fine fraction aggregates into a hot gas.
			Attrition cells and scrubbers	Attrition cells/scrubbers are designed to scrub the surfaces of particulates, liberate deleterious materials and break down pretend particulates associated with durability, such as hard-pan clays.

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
			Gravity column	Separates particles and materials according to their size and weight.
End of Life	Recycled materials are predominantly repurposed at a considerably lower value grade due to a lack of economic incentives and low commercial viability. Moreover, a lack of market mechanisms for recovery is apparent in the construction industry.	Ensure that tools and methods are developed and designed in a way that allows to retain value during deconstruction	Magnetic density separation	Magnetic density separation (MDS) is a technique that uses magnetised fluids to separate different types of plastic particles.
			Advanced dry recovery	A mechanical system of sorting and classifying wet crushed concrete particles according to their particle size.
Digital Technologies	The sector suffers from inertia that slows the adoption of new processes due to: • Lack of coordination and awareness between stakeholders, and across the value chain • Lack of adequate (circular) information and knowledge in building design and maintenance	Deploy technologies that enhance information sharing across the life cycle and value chain. Deploy technologies that enhance information retention	Augmented and virtual reality (AR/VR)	In the design stage, AR/VR can be used at the conceptual stage to explore the relationships between spaces. It can be also useful in the deconstruction stage, where it helps automatically classifying materials.
			Big data analytics Artificial intelligence	The term 'big data' is used to define large data sets which cannot be handled by typical software tools. In the construction industry, 'big data' may contribute to prolonging the lifespan of the

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
				products by providing insights into sustainability-oriented decision making during the operational phase. Artificial Intelligence (AI) refers to *“the ability of a computer or machine to mimic the capabilities of the human mind”* and consists of several subbranches using different techniques. In the construction industry, AI may contribute to design optimisation, optimised maintenance and the prediction of defects as well as end-use phases such as deconstruction.
			Digital platforms and marketplaces	From a technical perspective, a digital platform is understood as a software- based system providing core functionalities upon which derivative applications can be developed, while non-technical perspectives see it as a multi-sided network, matching different groups of users to exchange goods and

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
				services. In addition, digital platforms act as virtual markets, allowing access to and the exchange of goods; they facilitate the operation of product-service systems, enabling data collection for maintenance and repair; and they empower people to co-create circular products and services.
			Digital twins	Digital twins give a virtual replica of the physical world and are already commonly used in the automotive, aerospace and process industries to simulate performance. In the built environment, digital twins can be used for autonomous decision-making, feedback and control, predictive maintenance and so on.
			Digital passports Blockchain	One of the biggest obstacles to reusing and recycling resources in buildings is the lack of sufficient information about materials and substances at the end-of-use phase. Material passports address this information gap by storing a

Value Chain Stage	Key Problems	Key Solutions	Key Technologies	Description
				building's characteristics, location, history, material composition and other relevant parameters that help to frame a building along all its life cycles. Blockchain technology is based on a distributed peer-to-peer system that is cryptographically secured, enabling transparent value transactions without needing central authorities and intermediaries such as banks and government agencies. BCT offers support in managing and harmonising fragmented supply chains.

Energy-intensive industries ecosystem

Table 3: Energy Intensive Industries

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
		Chemicals		
Every year, millions of tons of manufactured chemicals are released into the environment as emissions, water discharges, and hazardous waste. This is in part due to technologies for chemical recycling being still at a low maturity	Develop new chemicals and processes that result in more sustainable products	Materials sourcing	Bio-based materials Inherent recyclability of materials	**Bio-based materials**: new processes and materials that optimise technical and ecological performance of products over their life cycle (e.g. self-healing cement or paint). **Inherent recyclability of materials**: technology advances to replace multicomponent, inherently difficult to recycle materials with single materials or a suit of materials that are more compatible to recycling. Technologies developing smart connections between different materials and enabling the recyclability of different connected materials.
Processing chemical materials can result in the release of hazardous waste streams to the environment and	The products of the chemical industry need to be decomposed and elements recovered and recycled after use.	Separation technologies	Separation technologies	**Improved separation technologies**: Technologies used to separate components in wastewater with a low eco footprint, including primary treatment and modular solutions.

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
chemical waste can be generated also as a by-product of manufacturing and after disposal after final use.		Regeneration of spent solvents	Regeneration of spent solvents	**Regeneration of spent solvents**: Regeneration of spent solvents essentially means purifying them. This is often done by (energy intensive) distillation. Innovations (for example, membranes) increase the energy efficiency, yield, and purity and expand the possibilities to treat spent solvents (used currently and used in the future); this increases the competitiveness of regeneration of spent solvents. Solvent recovery is a form of waste reduction. In–process solvent recovery is widely used as an alternative to solvent replacement to reduce waste generation. It is attractive, like end–of–pipe pollution control, since it requires little change in existing processes. Several different methods are used, including carbon absorption, distillation and condensation and dissolving the solvent.
		Recycling technologies	Upgrading secondary resources: - Recycling technologies for acids, alkaline, saline wastes - Recycling technologies for	**Recycling technologies for acids, alkaline, saline wastes**: existing technology includes electrodialysis. New technologies, like ion-exchangers, membranes, and

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			plastic waste (thermochemical recycling, chemical leaching and depolymerisation, biotechnological recycling, solvolysis, electrochemical, advanced separation technologies)	dialysis, can split these waste streams energy efficiently in acids and bases up to low concentrations with an increased selectivity. **Recycling technologies for plastic waste**: Chemical recycling is still in its infancy but has great potential and can be used to process biowaste. There are several technological routes for chemical recycling, and at this low stage of development it is unclear which routes offer the most potential. - **Thermochemical recycling**, such as gasification and pyrolysis, where waste is processed to obtain syngas and oil, respectively – substances that can be used to produce fuels and chemicals and substitute crude oil. The technologies allow processing relatively heterogeneous/ mixed waste streams - **Chemical leaching and depolymerisation** breaks a material down to polymers or monomers. This

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				method avoids downgrading waste as building blocks are recovered that can be used to produce new material equivalent to virgin materials based on fossil resources. A depolymerisation process has already been operated for polyesters and polyamides in the 90's, but most applications still have low TRLs and need to be better developed as they have high impact resource efficiency and circularity potential. Good tracking and sorting technologies also need to be developed, for example, for chemical recycling, a very clean and homogeneous waste stream is necessary. - **Biotechnological recycling**, in which enzymes or microbes are used to break down materials. This option still needs fundamental research - **Solvolysis**, a process that can

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				be used to separate composite plastics chemically using solvents. - **Electrochemical recycling of plastic waste/plasma**. Plasma gasification is used commercially as a form of waste treatment and has been tested for the gasification of refuse-derived fuel, biomass, industrial waste, hazardous waste, and solid hydrocarbons. - **Advanced separation technologies** to isolate disturbing contaminants from recycled materials.
		Digital technologies	Data collection technologies Coordination & management of connected processes Distributed ledger technologies	**Data collection technologies**: mapping of waste streams available (data digging that maps the production of waste streams, and the potential to use it) **Connected devices and systems** that monitor chemical applications can deliver significant efficiency improvements to production processes and foster circularity.

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			Modelling and simulation tools in material design Digital twins Digital process development/plant engineering	**Blockchain, or distributed ledger technolo**gy, is an emerging digital technology that has the potential to make a considerable positive impact on the chemical sector. Blockchain offers numerous potential benefits to the chemical industry by increasing traceability, safety and security, and improving compliance while lowering transaction costs. **Development and integration of modelling and simulation tools** in the materials design process on the path towards a landscape of interoperable digital tools from molecular simulation to life cycle assessment and end-of-use product and materials handling. **Digital twins** can significantly improve real-time process optimisation, operator training, asset construction and integration, and more. The best understood and most common type of digital twin in chemical engineering is the process digital twin – an integrated,

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				real-time digital version of the plant. The process twin replicates the flows and other state parameters of the process, and can be used for operator training, plant optimisation and remote support. **Digital process development and engineering**: Process design is increasingly done using reliable predictive simulation models of processes, pieces of equipment, and plants. However, several items still prevent the use of the full potential of the model-based approach.
The chemical industry is Europe's biggest industrial consumer of energy. It also relies on fossil fuels as feedstocks. Alternative technologies and feedstock remain unavailable due to price or lack of technology maturity	Improve production processes	Biomass processes (including biotechnologies)	Integration of bioenergy, waste, and other new fuels: - Biomass tolerant processes (biomass-based production, processes tolerant to variable feedstock); - Biomass pre-treatment processes	**Biomass an d bio-based processes**: Bio-based products are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised. **Biomass pre-treatment** are technologies that convert the biomass to a fuel with consistent characteristics that are equal to used fossil fuels. Pre-treatment technologies include mechanical

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				processing, drying, palletisation, steaming, pyrolysis and torrefaction.
		CO2 capture and use	Carbon Dioxide (CO2) as feedstock for the production of chemical and polymers - Advanced capture and purification of CO2 - Use of CO2 and CO as a building block in polymers	This is a process of **producing polymers from CO2 and not from fossil carbon**. The production capacity, mainly for polycarbonates and polyols for polyurethanes production, already amounts to more than 850 kt/a today, with an average weighted CO2-based carbon content of currently only 5.4 %[3]. However, many technical challenges still need to be overcome to enable the deployment of new CO2-conversion plants on a widespread basis, but the use of CO2 as a chemical feedstock for polymers has been intensively diversified in the last years. There are several successfully implemented technologies on the market or close to the commercialisation phase.
		Catalysis	Improved catalytic processes:	**Photocatalysis**: new multifunctional catalysts that can

[3] https://renewable-carbon.eu/news/carbon-dioxide-co2-as-chemical-feedstock-for-polymers-already-nearly-1-million-tonnes-production-capacity-installed/

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			- Photocatalysis - Electrocatalysis - Heterogeneous catalysts - Homogeneous catalysts - AI and machine learning to optimise the discovery of new catalysts	harness the energy of the sun directly to provide breakthroughs in the production of value-added chemicals from simple, sustainable building blocks like H20 and CO2. Advances will permit new combinations of compounds capable of undergoing cooperation redox chemistries, leading to radically new chemical processes for basic chemical building blocks. **Electrocatalysis**: electricity can be used to reduce chemicals and materials directly, or electricity can be used to generate alternative energy forms that can either accelerate reactions by improving mass transfer efficiencies or by providing different and more intense energy vectors. **Heterogeneous catalysts**: Advances in the reactive control and selectivity of heterogeneous catalysts will improve energy and resource efficiency. Increasing the lifetime of heterogeneous catalysts will reduce catalyst regeneration, replacement costs, and plant downtime. **Fully recyclable**

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				homogeneous catalysts: New homogeneous catalysts that can more easily be separated from the reaction products will provide significant advantages in resource and energy efficiency. New catalysts that are not dependent on critical raw materials can also lead to new and improved chemistries. **AI and machine learning**: Given a large dataset, it will be possible to develop artificial intelligence or machine learning tools to explore the catalyst/reaction parameter space and identify new, better catalysts for a host of different catalytic reactions.
		Wastewater treatment	Wastewater valorisation: - Valorisation of solutes from wastewater treatments - Valorisation of solids from waste-water treatments into new materials or energy production	**Valorisation of solutes from wastewater treatments**: Innovative conversion technologies that can valorise solubilised compounds to valuable chemicals, e.g. microbial production by fermentation or microbial conversion to polymers. **Valorisation of**

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				solids from waste-water treatments into new materials or energy production: Recovery of organics for reuse and, if necessary, biogas production and eventually energy production, inorganics (phosphates and nitrates for application in fertilisers), and trace metals/components (e.g. magnesium, calcium, precious metals). This includes modular solutions.
Steel				
During the steelmaking process an important amount of by products are currently wasted and not sufficiently reused.	Improve residue recovery and valorisation/reuse		Slag valorisation technologies	Wet and dry granulation technologies are used to transform steelmaking slag into a secondary raw material. The wet granulation of slag guarantees fast cooling and high production rates but requires water treatment. Dry slag granulation provides an opportunity to have no wastewater and a reduction in costs, with the possibility to recover heat, but it can have limitations regarding the flow rate. Different dry granulation solutions exist that can be adopted for specific needs for EAF or ladle furnace (LF)

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			35	slag granulation[4].

[4] https://www.mdpi.com/2075-4701/11/8/1202/htm

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			Zinc and iron recovery technologies: - RecoDust for Fe and Zn recovery from BOF dust - Leaching process for Zn recovery from Basic Oxygen Furnace (BOF) sludge - Induction furnace & bath injection for Zn recovery	RecoDust is believed to be an efficient way of processing steel mill dusts to produce reusable secondary raw material resources[5]. By partial and selective removal of zinc from the BOF sludge, the residual sludge can be used as a secondary iron resource in the blast furnace. For simultaneous recovery of iron and zinc from filter dust, a new melt bath injection process has been tested in industrial environment. The main aspect of this technology is to inject pneumatically conveyable, Zn- and Fe-bearing filter dust via a submerged lance into the iron melt bath of an induction furnace. By reduction with carbon, metallic iron is formed, which is used as cast iron product. [6]

[5] Johannes Rieger et al, 'RecoDust—An Efficient Way of Processing Steel Mill Dusts' April 2019Journal of Sustainable Metallurgy 5(11)

[6] Gerard Stubbe et al, 'Zinc and Iron Recovery from Filter Dust by Melt Bath injection into an Induction Furnace', available at: https://www.velco.de/wp-content/uploads/2021/05/Erzmetall_Schmelzinjekt2016-1.pdf

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			By process residue valorisation: -MIDREX ® residue agglomeration for reuse in Direct Reduction (DR) -Waste plastic gasification for syngas production -Two-step dust recycling of Electric Arc Furnace (EAF) dust -Reuse of waste refractories	MIDREX® is a mechanical reduction process generating various iron-oxide containing residues, which can be screened in terms of oxide fines and dried sludge[7]. In gasification, plastic waste is reacted with a gasifying agent (e.g., steam, oxygen and air) at high temperature around 500–1300 °C, which can produce synthesis gas or syngas[8]. EAF dust recycling via reduction roasting has gained increasing attention over the last years. The process vaporises the intended metals but there are remaining pellets that can be sold back to iron companies to be used again in the steel making process[9]. Refractory materials are essential for the production of iron and steel. The largest consumption of refractories corresponds to steel ladle and Basic Oxygen Furnac (BOF) lining, as well

[7] Rieger,J.;Colla,V.;Matino, I.; Branca, T.A.; Stubbe, G.; Panizza, A.; Brondi, C.; Falsafi, M.; Hage, J.; Wang, X.; et al. Residue Valorization in the Iron and Steel Industries: Sustainable Solutions for a Cleaner and More Competitive Future Europe. Metals 2021,11,1202. https:// doi.org/10.3390/met11081202

[8] Dang Saebea et al, Gasification of plastic waste for synthesis gas production, Energy Reports Volume 6, Supplement 1, February 2020, Pages 202-207

[9] Feeco International, 'A Look At The Process Of EAF Dust Recycling', available at: https://feeco.com/a-look-at-the-process-of-eaf-dust-recycling/

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				as blast furnace / cahouse[10].
Metal recovery processes do not allow to capture the full value of metal wastes	Enhance the recycling of steel		**Metal scrap characterisation technologies** - Xray technology - Infrared scanning - Laser object detection (LOD) - Software: routing software, inventory management, anti-theft compliance, document signing, - Artificial Intelligence (AI) detection	X-ray technology can be used as a sorting technology th at uses X-rays to distinguish between high- value metal alloys found in scrap of many shapes and sizes. The use of infrared imaging is varied. It is very beneficial to the melt shop by viewing full ladles of molten steel. Once the scrap metal is melted in a melt furnace, the

[10] Jorge Madias et al, 'A review on recycling of refractories for the iron and steel industry', September 2017 Conference: UNITECR 2017 Project: Environmental Technology

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			system technology	molten steel is poured for transfer to the next operation. The exterior of the ladle is scanned with an infrared camera. In addition, infrared cameras are also introduced in the thermoforming process to reduce scrap volume. Laser Object Detection system can boost the circuit's sorting capabilities, allowing waste and scrap recycling operations to reach improved final product purity levels. Recycling software helps recycling centres and scrap yards run their businesses more easily by collecting data and running reports. Artificial intelligence (AI), machine learning (ML), deep learning, and neural networks can serve to interpret metallic scrap inspection images. Technologies can significantly reduce operator workload and allow a more efficient and effective means of determining pure metal scrap.
			Metal scrap collection and sorting technologies - Robotic sorting	Robotic picking systems can sort the different alloys of metal scrap, such as different aluminium and stainless-steel

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			- Automatized sifting of mixed waste streams (LIBS)	alloys, manganese, copper, brass and lead. Opportunities are being investigated to combine robotic sorting with innovative computer vision, LIBs and other sorting technologies. Laser-induced breakdown spectroscopy (LIBS) is an analysis technique that determines the elemental composition of a target material. It was confirmed that 25% higher maximum classification accuracy was achieved when LIBS spectra were acquired from optimized rather than non-optimized (i.e., contaminated) surfaces[11].
		Ceramics		
Ceramic and glass production processes result in a number of environmental issues	Design for circularity	Alternative design of technologies	Sustainable process design: sustainable manufacturing process of porcelain stoneware ceramic tiles based on ceramic body dry preparation	**Sustainable manufacturing based on ceramic body dry preparation** is an alternative to the wet route that has been used most the world.

[11] https://www.researchgate.net/publication/353257425_3D_Sensing_System_for_Laser-Induced_Breakdown_Spectroscopy-Based_Metal_Scrap_Identification

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
(air, water pollution; high energy consumption; waste generation; noise). There is a need to: • Address dual goal of closing loops and emissions reduction • Adapt technical requirements of installations				The wet route ensures the high quality of the product; however, it is water and energy intensive. Challenges lie in securing the quality of a product in the dry manufacturing based on dry milling and granulation systems. Some promising innovations have been emerging in addressing this challenge. Further investment in the design of such technologies is needed.
			Design for resource and energy efficient kilns	**New generation of kilns** in a more resource and energy efficient design can be based on diverse innovative technologies. Such solutions include for example radically improved architecture for ceramic industrial furnaces, characterised by optimised energy consumption, reduced emissions, and lower operating costs compared to currently available practices.
			Eco-design with lifecycle thinking, e.g. reduction in products thickness, CO2 integration for improved quality	By **incorporating lifecycle thinking in product design** one can avoid 70-80% of environmental impact of a product. In ceramic industry a large variety of eco- and circular design strategies can be integrated for instance into the selection of low

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				impact materials, reduction of material use by lighter product design, assuring quality and reduction of breaks via new components and more practical shapes, design products with better thermal, mechanical, etc performances, design of multifunctional products (e.g. tiles with integrated photovoltaics), new method for installation/dismantling that allow reuse, etc. Reduction in tile thickness (e.g. from 12 mm to 4 mm) offer significant material savings while securing the performance. CO2 integration/carbonisation demonstrated improves qualities for bricks.
	Improve manufacturing processes efficiency	Industrial symbiosis	Industrial symbiosis/regional symbiosis	**Industrial symbiosis** with other industries can offer the following possibilities: - Use of side streams or end of life waste of construction industries and building sector - Climate change solutions based on local industrial/ regional symbiosis – Tracking and Tracing end-of-life Ceramic products across Value Chain)

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				- Use of industrial and inorganic wastes tested as substitutes to raw materials (mill scale, pet coke, glass waste, carbon solid residue from the pyrolysis of used tyres, cement asbestos wastes, roof tiles, aluminium electrostatic painting sludge, etc)
		Use of waste	Use of side streams, end of life ceramic waste, industrial and inorganic waste	**Reuse of internal production residues or supply chain cooperation for recycling** is focused largely on closing the loops within the ceramic value chain, feeding side streams of specific process stages to another processes.
			Use of organic waste as substitutes to the clay raw material	**Use of organic waste** can substitute the clayey raw material including for example municipal waste, sewage sludge, olive mill waste, olive stones, wooden residues, waste from sugar production.
		Water recovery	Industrial deployment of condensation and gas purification systems for water recovery and re-use	This technique allows water recovery by condensing water vapor contained in the flue gas and by passing through low temperature water from the permeate side.

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			Solutions for effluent/wastewater (reclaimed water) reintegration in ceramic production	Reuse of water used in the manufacturing process is a very good resource efficiency measure that can help saving production costs for the ceramic manufacturers, as well as reduce their water footprint. Water can be recovered via the **reintegration of effluent/wastewater in ceramic production.** Product manufacturing of ceramic industries causes high volumes of effluents that have to be collected, treated, deposited. By recycling these effluents, the amount of fresh water and raw materials needed for preparing the slurry in ceramic production can be reduced.
			Recovering and reusing of water evaporated in spray drying step of the ceramic process, for the preparation of slurries	Water and energy can be saved in ceramic tile spray-drying processes by **recovering and reusing water evaporated in spray drying step** of the ceramic process, for the preparation of slurries. Reuse of water used in the manufacturing process is a very good resource efficiency measure that can help saving production costs for the ceramic manufacturers, and it can reduce their water footprint.
		Optimisation	Waste heat storage and later use e.g. in	**Heat recovery from flue gasses and use**

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
			drying process	**in the ceramic ware drying process:** the aim of this process is to recover the heat given off by the combustion of gases in the kilns and re-use it in one of the two pre-dryers the plant possesses. This will help reducing fuel consumption and consequently the emissions this produces. This improvement is shown to be economically feasible by the benefit obtained from fuel savings (Bovea 2010, Ibáñez-Forés 2013).
			Optimisation of the sintering/firing process: Liquid phase sintering, pressure assisted sintering, microwave sintering, field assisted sintering, flash sintering, spark-plasma sintering	**Optimisation of the sintering/firing process:** To reduce the sintering temperature and sintering time, R&D efforts of researchers are focused on technologies such as liquid phase sintering, pressure assisted sintering, microwave sintering, field assisted sintering, flash sintering (Cologna et al., 2010).
			Cold sintering process	**Cold Sintering Process** R&D demonstrated for a sintering technique for ceramics and ceramic-based composites, using water as a transient solvent to effect densification (i.e. sintering) at temperatures between room temperature and 200 °C. To

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
				emphasize the incredible reduction in sintering temperature relative to conventional thermal sintering this new approach is named the “Cold Sintering Process” (CSP). Basically CSP uses a transient aqueous environment to effect densification by a mediated dissolution–precipitation process. The properties of selected CSP samples are demonstrated to be essentially equivalent as samples made by conventional thermal sintering. (Guo J. et al., 2016; Guo H. et al., 2016).
			Paint use minimisation via digital printing on ceramic surfaces	In the wall and floor tiles industry, some manufacturers have switched from rotary printing to **digital printing:** ceramic inks can be used instead of decorative pastes, so that only 20% of the raw material previously needed is used. Moreover, broken ware is minimised since the mechanical load on the tile is eliminated. Research on the future potential for the application of digital printing in the glazing process is performed (CeramUnie 2020).
Post consumption ceramic waste is often	End of life	Improve recycling and waste collection	(System for) Collection, sorting and separation of waste/ sensor	Complementary technologies assuring an **efficient system for collection, sorting**

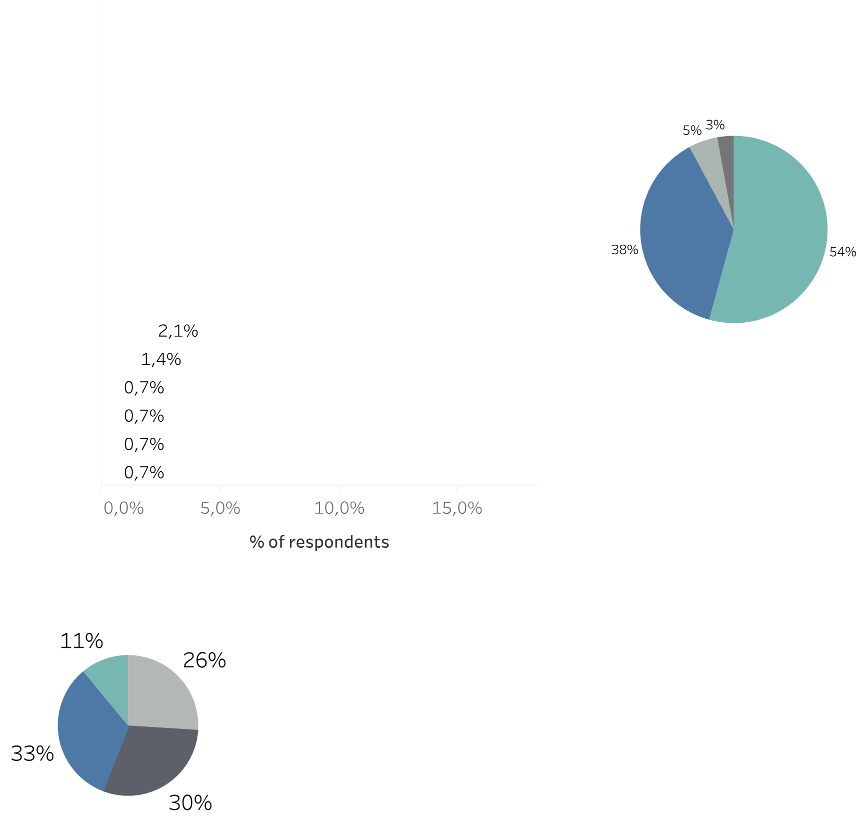
Key Problems	Key Solutions	Technology groups	Key Technologies	Description
landfilled rather than recycled (especially in the construction sector). This is due to: • Lack of an efficient system for collection, sorting and separation of waste • Lack for policy and regulatory incentives for recycling		processes	technologies	**and separation of waste** such as post-consumer ceramic, construction waste, dust and residues are of important area for innovation and improvement. Setting well-functioning system is crucial for enabling circular/recycling technologies listed above.
			Recycling of post-consumer ceramic – take-back programme	**Recycling technologies** for the post-consumer ceramic includes recapturing of valuable secondary materials for (re)manufacturing of high tech and research ceramic), as well as grinding, milling and reapplying of standard ceramic waste, which are rarely practiced. “Take-back scheme” is an arrangement organised by a manufacturer or retailer, to collect used products or materials from consumers and reintroduce them to the original processing and manufacturing cycle.
Environmental footprint across the life cycle of the ceramic production is still high. Unsustainable sourcing of resources, their	Optimisation of processes, reduction of process related waste streams	Digital technologies	Digitalisations technologies for resource monitoring and circularity	**Digitalisations technologies for resource monitoring and circularity:** The evolution towards Industry 4.0 in ceramic manufacturing consists of integrating new

Key Problems	Key Solutions	Technology groups	Key Technologies	Description
suboptimal use (not only core materials, but also water, energy and supplementary input materials) during the production processes are part of the challenges associated with the traditional linear economy in the ceramic industry.				production technologies in order to improve working conditions and increase productivity and quality, as well as monitor environmental performance in each part of the technological chain and adopt necessary interventions to reduce this impact (Garcia-Muiña 2018).
	Providing access to the product footprint information	Digital technologies	Digital Product passport	**Digital product passport** can be a valuable tool enabling quick and convenient access to and sharing of product-related information. Easy access to information could empower consumers to purchase more circular products or inform repairers on how to fix used devices.

ANNEX 3 | SME SURVEY

As part of this roadmap, a business survey was implemented between 30th October and 15th December 2021 with the objective to gathering feedback about technological trends and challenges faced by technological companies and start-ups. The survey questionnaire was targeted specifically at firms that develop circular industrial technologies sourced from the Eutopia and Crunchbase data sources (contacts had been obtained in respect of GDPR), but also advertised through networks of green technology service providers. In total, 140 responses (119 full responses and 21 partial responses) were received in the field of circular industrial technology with varied representation across EU Member States. The country from which most of the responses were collected is Germany, followed by Italy and the Netherlands. These four countries represent ca. 40% of the respondents.

Figure 1 Geographical coverage of the respondents and share according to size class and age of the companies



Source: Technopolis Group analysis

The respondents were from organisations of different sizes: organisations with less than 10 employees provided 52% of the responses, while small organisations with 10 to 59 employees represent 40% of the responses. In a smaller proportion, this sample is completed by 4% of organisations with 50 to 249 employees and by 4% of organisations of more than 250 employees.

ANNEX 4 | OVERVIEW OF NATIONAL INVESTMENTS AND PROGRAMMES OF EU MEMBER STATES AND NORWAY

Austria

Main national policy strategies:

According to the Ministry of Environment, Austria aims to become climate neutral by 2040. The Austrian national climate and energy strategy envisages a 36% reduction in GHG emissions by 2030 compared to 2005 in sectors not subject to the EU emissions trading system.[12]

The Federal Ministry has prepared a national circular economy strategy in 2021[13] and launched its implementation. The overriding goals of the Austrian circular economy strategy are the reduction of material consumption, the increase of resource and thus also energy efficiency, the replacement of primary raw materials by secondary raw materials, the replacement of fossil raw materials by biogenic raw materials, and a largely fossil-free and climate-neutral production. The necessary massive reduction of greenhouse gases (by 45%) can only be achieved through changes in the production of basic materials and material goods. The focus areas of the strategy include construction and building infrastructure, mobility, waste management, biomass, textiles and clothing, plastics and packaging and electrical and electronic equipment.

National programmes and initiatives:

The *RTI Initiative Circular Economy*[14] is a multi-annual programme that supports applied research, technology development and innovation in the circular economy. Projects that receive support include the transformation of the linear economic system to circular following the introduction of new technological approaches and innovative solutions, projects that serve to intensify product use, innovations that optimise the use of resources and the development of innovative solutions that close material cycles.

The *Circular Futures*[15] is a circular economy platform that aims at accelerating the transition to a circular economy in Austria and Europe.

The *National Reform Programme 2022 of Austria* includes several measures addressing topics such as the circular economy, prevention of waste, and preservation of biodiversity, such as the 'funding for deposit return systems' in retailing, the 'promotion of the repairing of electrical and electronic equipment', and the 'establishment of a biodiversity fund'[16].

[12] https://energy.ec.europa.eu/system/files/2020-03/at_final_necp_main_en_0.pdf
[13] https://www.bmk.gv.at/themen/klima_umwelt/abfall/Kreislaufwirtschaft/strategie.html
[14] https://www.ffg.at/FTI-kreislaufwirtschaft#:~:text=Die%20FTI%2DInitiative%20Kreislaufwirtschaft%20richtet,(abh%C3%A4ngig%20vom%20F%C3%B6rderinstrument)%20m%C3%B6glich.
[15] https://www.circularfutures.at/ueber-uns/english-language-summary/#:~:text=Circular%20Futures%20was%20initiated%20by,economy%20in%20politics%20and%20legislation.
[16] https://ec.europa.eu/info/sites/default/files/nrp_2022_austria_en.pdf

Budget:

EUR 10 m[17] were allocated for the RTI Initiatives' first call (2021) and EUR 12 m for the second call[18] (2022). Both calls for proposals of the Ministry supported the development of innovative technologies and systemic innovations that took into account the entire life cycle of goods and focused on enabling the circular economy.

In 2022 and 2023 the Ministry of Environment is expected to spend EUR 60 m in total for applied research, internships, studies and innovative public procurement with relevance for circular economy.

Austria's National Recovery and Resilience Plan: Under the 'Sustainable recovery' goals of Austria's plan, the subcomponent 1.C 'Biodiversity and circular economy' introduces the reform 'Legal framework to increase collection rates for plastic beverage packaging and the supply of reusable containers in the food retail sector' and four investments worth EUR 350 m: 1) Biodiversity Fund, 2) Investments in empty take-back systems and measures to increase re-usage rates for beverage containers, 3) Installation and retrofitting of sorting facilities, and 4) Support for the repair of electrical and electronic equipment.[19]

Belgium

Main national policy strategies:

In Belgium, initiatives and projects related to eco-innovation and the circular economy are mostly carried out by policies and programmes at the regional level. Each region has a specific strategy for the circular economy.

The Walloon government published its strategy dedicated to the circular economy called *'Circular Wallonia'* in 2021 (for the period 2021-2024). The programme is a continuation of previous actions launched under the Marshall Plan 4.0 promoting the reuse and management of waste. Circular Wallonia has ten ambitions for example to become a pioneering region in circular innovations and a leader on a European scale; and manage natural resources in a circular way. Six value chains are addressed notably textiles, construction, metallurgy, plastics, food and water.

The Government of Flanders published its strategic policy paper called 'Vision 2050, a long-term strategy for Flanders'[20] in 2016, where the transition towards the circular economy has been one of the seven transition priorities.

The Brussels-Capital Region has developed a strategy and programme to accelerate its transition to a circular economy model. *Shifting Economy* is the economic transition strategy of the Brussels-Capital Region, which has medium- and long-term objectives, as follows: a) by 2030, public financial resources should be reoriented towards more sustainable/socially responsible businesses (or at least those initiating a move in that direction), b) by 2050, the regional economy should be completely decarbonised. Thus, the circular economy is an important pillar of this strategy.[21] Under the *Resources and*

[17] https://www.greentech.at/wp-content/uploads/2021/05/BMK_Jakl_KWSAT-Praesentation_GT-Summit_4-2021.pdf
[18] https://www.ffg.at/2-ausschreibung-fti-kreislaufwirtschaft
[19] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021SC0160&qid=1624626088799
[20] https://www.vlaanderen.be/publicaties/vision-2050-a-long-term-strategy-for-flanders
[21] https://smartcity.brussels/news-258-regional-programme-for-the-circular-economy

Waste Management Plan 2018-2023[22], there are sixty measures to reduce waste generation and increase reuse and recycling.

National programmes and initiatives:

Circular Flanders is the "hub and the inspiration for the Flemish circular economy"[23]. It is a partnership of governments, companies, civil society, and the knowledge community that will take actions together.

The Brussels-Capital Region has developed know-how, including through the *Regional Programme for Circular Economy* (2016-2021), which improved the capacity of economic actors in different fields, such as food and water. The path taken by the construction sector is a good example in this respect. There is a dedicated roadmap, called '*Reuse'*[24] for the reuse and recuperation of equipment and materials in the construction sector. The economic actors in this particularly sensitive sector have developed a unique expertise in the circular economy and follow ambitious standards for the energy performance of buildings. In the textile sector, there are few circular economy initiatives that are relevant such as various textile laboratories called 'Fablab textile', 'R-use fabric', 'Coucou' and 'Jukebox'. The call for proposals entitled 'Be Circular Be Brussels' offers grants to entrepreneurs and businesses of all sizes with a circular economy idea since 2016. Under its call for proposals in 2020, EUR 2 m were available for direct support to SMEs. The citydev Darwin project[25] houses different enterprises in the circular economy, whereas 'Greenlab'[26] serves as an accelerator for circular economy start-ups. Circlemade[27] is a network of pioneers in the circular economy. CiReDe (Circular Regulation Deal)[28] is an instrument for the identification and removal of administrative barriers to the circular economy.

Budget:

Between 2019 and 2022, the Flemish Government will invest around EUR 120 m in circular innovation[29]. Circular Wallonia has an estimated budget of over EUR 200 m to ensure the deployment of the circular economy[30] (for the period of 2021-2024).

Bulgaria

Main national policy strategies:

The *draft Strategy for transition to the circular economy for the period 2022-2027*[31] defines three strategic objectives related to the development of the circular economy. The first one is focused on green and competitive economy and particularly on the achievement of higher resource productivity; new circular business models; and the contribution of the country to the supply of critical raw materials in EU. The second objective is focused on waste prevention and more sustainable use of resources. The

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22 https://environnement.brussels/nos-actions/plans-et-politiques-regionales/action-de-la-region
23 https://circulareconomy.europa.eu/platform/sites/default/files/kick-off_statement_circular_flanders.pdf
24 https://reuse.brussels/
25 https://www.circulareconomy.brussels/localisation/citydev-darwin/
26 https://hub.brussels/fr/greenlab-accelerateur-pour-start-ups-durables/
27 https://www.circlemade.brussels/
28 https://www.circulareconomy.brussels/wp-content/uploads/2019/10/190404_CIREDE_RAPPORT_FINAL_GOUV.pdf
29 https://vlaanderen-circulair.be/en/blog/detail/circular-economy-monitor-for-flanders-launched#:~:text=Between%202019%20and%202022%2C%20the,for%20the%20period%202022%2D2026.
30 https://circulareconomy.europa.eu/platform/sites/default/files/resume_de_la_politique_wallonne_en_v1_1.pdf
31 https://www.moew.government.bg/

third objective is about encouraging more sustainable consumption and behavioural patterns, as well as support for the social and green economy[32].

National programmes and initiatives:

The *National Development Programme Bulgaria 2030* is the country's strategic framework describing in detail the areas of impact that will be subject to targeted interventions by 2030, ranked by priorities and sub-priorities and accompanied by result indicators, indicative financial resources, sources of funding and relevant UN Development Goals. The document sets out 13 national priorities including the transition to a circular and low-carbon economy. Actions will be taken to increase resource productivity and circular (secondary) use of materials; to support enterprises in introducing zero-waste technologies; to reduce the amount of waste generated in the production process; and to develop industrial symbiosis. Implementation of business models that allow interaction between products and services throughout the supply chain as well as design, reuse and recycling strategies ensuring longer product use will be promoted. A special focus will be placed on R&D and innovation related to the circular economy.

National Recovery and Resilience Plan (NRRP) includes a set of measures and reforms with the objective to restore and support the economic growth of the country. At the same time, the NRRP lays the foundations for a green and digital transformation of the economy in the context of the ambitious goals of the European Green Deal[33].

Budget:

National Recovery and Resilience Plan (NRRP), *Investment 2: Programme for economic transformation* - 'Green transition and circular economy' includes BGN 180 m (EUR 92.3 m) to support access to financing for SMEs in their transition to a circular economy (with focus on circular business models, clean technologies)[34]. The 2021-2027 Operational Programme *'Competitiveness and Innovation in Enterprises'* incudes measures targeting resource efficiency with a focus on product design, as well as waste management (EUR 48 m); innovative products, process and circular business models (EUR 30 m for design and EUR 126.92 m for implementation); industrial symbiosis (EUR 10 m); investments to improve resource efficiency (EUR 11.91 m); support for enterprises in industrial parks for clean technologies, circular and low carbon economy (EUR 69.1 m).[35]

Croatia

Main national policy strategies:

Croatia does not have a dedicated circular economy strategy; however, the government has acknowledged the importance to take actions in the area of waste reduction, waste separation and redirecting waste streams to new use[36]. Circular economy approaches have been integrated into the current National Waste Management Plan.

32 https://www.minfin.bg/en/1394
33 https://nextgeneration.bg
34 https://nextgeneration.bg/1#modal-one
35 https://opic.bg/public/opik/nov-programen-period-2021-2027-g
36 See also: https://www.worldbank.org/en/country/croatia/brief/croatia-circular-economy-approaches-in-solid-waste-management#:~:text=The%20Government%20of%20Croatia%20has,treating%20waste%20as%20a%20resource

National programmes and initiatives:

No information identified

Budget:

No information identified

Cyprus

Main national policy strategies:

The *Cyprus Action Plan for the transition to a circular economy 2021-2027* was launched by the Ministers of Energy, Commerce and Industry and Agriculture, Rural Development and Environment and the Deputy Minister of Research, Innovation and Digital Policy in 2021[37]. The pillars of the action plan include fostering a cultural change towards the circular economy, providing incentives for investments in a circular economy, the development of circular economy infrastructures and municipal waste management.

The *Cyprus Circular Economy Network (CCEN)* has been initiated by the Cyprus Federation of Employers & Industrialists to set up a network of 5 strategic partners in Cyprus: International and European Collaborators, Supporters and Members. The objective of CCEN is to enable and accelerate the transition of Cyprus' economy to a circular and green economy, offering its services in a multilevel stakeholder approach including businesses, academia, and the public sector, and contributing to the achievement of the economic and social resilience of Cyprus for a sustainable future.[38]

National programmes and initiatives:

No information identified

Budget:

The total budget of the action plan is EUR 90 m. Grant schemes and an incentive scheme of EUR 13 m are expected to be announced that will support industries to launch circular projects[39].

Czech Republic

Main national policy strategies:

Circular Czechia 2040 (under development): The Czech Ministry of Environment is working on a national circular economy strategy called '*Circular Czechia 2040'*, since 2018.[40] Most recently in 2021, the OECD published the report *Towards a national strategic framework for the circular economy in the Czech Republic* in cooperation with

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[37] https://cypruscircular.org.cy/wp-content/uploads/2021/08/27.7.2021.MECI_.Circular-Economy-Minister-Presentation.pdf
[38] https://cypruscircular.org.cy/mission-vision/
[39] https://cypruscircular.org.cy/cyprus-action-plan-circular-economy/
[40] https://incien.org/wp-content/uploads/2021/06/circular_czechia.pdf

the Directorate General for Structural Reform Support (DG REFORM) of the European Commission to support the Czech government developing its Circular Economy Plan.[41]

Secondary raw materials strategy of the Czech Republic: This piece of legislation, in place since 2014 with updates every two year, is one of the main policies the Czech government promotes as being "another important step for our country to achieve a change in the resource management system from a linear to a circular one".[42] The aim of the latest update of this policy for 2019-2022 is mainly to increase the share of raw materials returned to the economy from the total raw material consumption in the Republic.[5]

National programmes and initiatives:

No information identified

Budget:

No information identified

Denmark

Main national policy strategies:

Action Plan for Circular Economy: In July 2021, the Danish Ministry of Environment released this action plan as Denmark's national plan for the prevention and management of waste in the period 2020-2032. The action plan targets the entire circular value chain and has three focus areas: biomass, construction, and plastics. There are a total of 129 initiatives in the action plan in coherence with previous environmental plans, including *Climate Plan for a Green waste sector and Circular Economy* (2020), *Strategy for Green Public Procurement* (2020), *National Strategy for a Sustainable Built Environment* (2021), *Strategy for Circular Economy* (2018), and *Action Plan on Plastics* (2018). The comprehensive set of quantitative indicators and targets set in this action plan is one of its distinctive features.[43]

The Strategy for Circular Economy is the predecessor to the Danish Action Plan for Circular Economy, launched in 2018 for a four-year period. The Danish Ministry of Environment and Food and the Danish Ministry of Industry, Business and Financial Affairs introduced this strategy based on the recommendations of the Danish Advisory Board on Circular Economy. This Strategy proposed initiatives within six thematic areas: 1) Strengthening enterprises as a driving force for circular transition; 2) Supporting circular economy through data and digitalisation; 3) Promoting circular economy through design 4) Changing consumption patterns through circular economy; 5) Creating a proper functioning market for waste and recycled raw materials; 6) Getting more value out of buildings and biomass.[44]

Denmark Without Waste: The Danish Ministry of Environment published a set of waste management strategies in 2013 (*Denmark Without Waste – Recycle More, Incinerate*

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[41] https://www.oecd.org/fr/environnement/towards-a-national-strategic-framework-for-the-circular-economy-in-the-czech-republic-5d33734d-en.htm

[42] https://www.mpo.cz/cz/prumysl/politika-druhotnych-surovin-cr/ceska-republika-se-priblizuje-k-cirkularni-ekonomice--vlada-cr-schvalila-politiku-druhotnych-surovin-ceske-republiky-pro-obdobi-2019-_-2022--248121/

[43] https://www.en.mim.dk/focus-on/circular-economy/

[44] https://circulareconomy.europa.eu/platform/en/strategies/danish-strategy-circular-economy

Less[45]) and 2015 (*Denmark Without Waste II – Strategy for Waste Prevention*[46]) that are the first records of a circular approach towards waste treatment in Denmark.

National programmes and initiatives:

DKK 125 m is dedicated under the *Circular Economy Beyond Waste* project for the period 2022-2030 to ensure full implementation of the Danish Action Plan for the Circular Economy. EUR 10 m of this fund is granted by the EU's LIFE IP programme and the rest is provided by the Danish project partners. A consortium of 40 Danish partners including municipalities, governmental bodies, and universities deliver this project under the leadership of the Region Midtjylland (Central Denmark Region).[47]

For the period 2021-2027, EUR 247 m will be granted to Danish SMEs under the European Regional and Development Fund (ERDF). This fund has a range of objectives, among which is promoting circular economy practices within the Danish business sector.[48]

Budget:

DKK 125 m for 2022-2030 (approx. equivalent to EUR 17 m)

Estonia

Main national policy strategies:

Estonia is currently developing its national circular economy strategy and action plan. The documents are being prepared by the Ministry of Environment[49] and are foreseen to be published early 2023.

To ensure a reasonable strategy that takes into account the principles of the circular economy and resource-efficiency, Estonia is currently assessing the status and future possibilities of the circular economy, including interest groups and learning from the experience of other countries.

National programmes and initiatives:

Ecodesign has been addressed and developed, along with the national bioeconomy strategy. Resource efficiency has been addressed through programmes and support schemes.

Budget:

No information identified

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[45] https://eng.mst.dk/air-noise-waste/waste/denmark-without-waste/
[46] https://eng.mst.dk/air-noise-waste/waste/denmark-without-waste-ii/
[47] https://webgate.ec.europa.eu/life/publicWebsite/project/details/5809
[48] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3304
[49] https://ringmajandus.envir.ee/en/creating-strategy-and-action-plan-circular-economy-estonia

Finland

Main national policy strategies:

Finnish roadmap to a circular economy 2016-2025: In 2016, the Finnish Innovation Fund *Sitra* collected the key actors' opinions about the requirements of a transition to a circular economy in Finland. The results were put together and published as a roadmap to define the role of government, cities, businesses, and consumers in the move towards a circular economy in Finland.[50] This roadmap is the first national circular economy roadmap in the world and played a crucial role in shaping the Finish government's programme for a circular economy.[51] Following a revision of the initial roadmap, the second edition was released entitled '*The critical move – Finland's roadmap to a circular economy 2.0*' in 2019.[52]

National programmes and initiatives:

Strategic Programme for Circular Economy: In a cooperation between different stakeholders, including Finish Ministries of Environment and Economic Affairs, and multiple research institutes, Finland adopted its *Strategic Programme for Circular Economy* in April 2021. This strategy envisions 'Finland in 2035: "Our economic success is founded on a carbon-neutral circular economy society' and sets the objectives, indicators, measures, and resource allocation in order to achieve a systemic transition to circular economy in Finland 2035".[53]

Budget:

The Finland's *Strategic Programme for Circular Economy* comes with a comprehensive description of the budget allocations: "A total of EUR 2.3 m has been allocated to the promotion of the circular economy by the Ministry of the Environment and EUR 3 m by the Ministry of Economic Affairs and Employment in 2020-2022. In addition, EUR 38 m has been allocated to the Ministry of Economic Affairs and Employment as future investments in aid for the circular economy and sustainable growth in 2020-2021. In addition to the current resources, the implementation of the programme would be supported by the following additional resources allocated to the items of the responsible ministries:

- EUR 200-250 m for RDI and ecosystem activities promoting a low-carbon circular economy and for investments in demonstrations and facilities predominantly paid from the EU recovery instrument's funding in 2021-2026.
- EUR 9.2 m in appropriations to finance operating models supporting public procurement, industrial symbioses, ecosystem development, regional circular economy work and product design in 2022, EUR 14 m in appropriations a year in 2023 and 2024, and EUR 12 m in appropriations in 2025.
- a total of EUR 1.7 m for the implementation of one-off measures (scenario work, drawing up sectors plans, promotion of the recycling markets and reports related to financial steering) in 2022, and EUR 0.5 m in 2023."

[50] https://media.sitra.fi/2017/02/28142644/Selvityksia121.pdf
[51] https://sustainabilityguide.eu/?guide=roadmap-to-a-circular-economy
[52] https://www.sitra.fi/en/projects/critical-move-finnish-road-map-circular-economy-2-0/
[53] https://ym.fi/en/strategic-programme-to-promote-a-circular-economy

France

Main national policy strategies:

Circular Economy roadmap of France: The France circular economy roadmap was announced in 2018 and called for a broad effort (from citizens, consumers, local governments, businesses, and the state) to secure a successful energy/ecology transition and to conclude France's linear produce-consume-discard model. The roadmap reflects the national societal initiative to get rid of the 'consume and discard' model.[54]

French act of law against waste and for a circular economy: The French act of law (2020) contains about 50 measures providing for: new obligations with the creation of new producer responsibility sectors to include new product families in the circular economy (toys, sports and do-it-yourself equipment, building materials, cigarette butts, sanitary textiles); new prohibitions on single-use plastics and to fight waste of food and non-food unsold products; new tools to better control and sanction offences against the environment (greater power for mayors to combat littering and illegal dumping), to support companies in their eco-design initiatives (bonus/malus-type incentives) and to assist citizens in new consumption practices (repairability index, information on environment and health impacts of products, harmonisation of info on sorting, etc.).[55]

National programmes and initiatives:

The *French Recovery Programme*[56] aims to enable the economic, social and ecological rebuilding of the country over the period 2020-2030. The document is divided into three major topics: ecology, competitiveness and social cohesion.

In this programme, EUR 200 m has been entirely dedicated to the circular economy over the period from 2021 to 2022. ADEME, the French State Agency for Ecological Transition, has strengthened its fund dedicated to the development of prevention and recycling. With the creation of the areas related to responsible consumption and production, ADEME intervenes in the territories and mainly at the local level with, at present, with a fund of EUR 200 m per year. In September 2021, the French government announced the launch of a new strategy for Recyclability, Recycling and Reincorporation of Materials, as part of the *French Recovery Programme* and the *4th Investments for Future Programme* (*PIA4*). In addition, an extra fund of EUR 370 m was added to support innovation for the circular economy over the period 2021-2027.[57]

Budget:

EUR 200 m for 2021-2022, EUR 370 m for 2021-2027.

[54] https://www.ecologie.gouv.fr/feuille-route-economie-circulaire-frec
[55] https://www.service-public.fr/particuliers/actualites/A13849?lang=en
[56] https://www.economie.gouv.fr/plan-de-relance#:~:text=Le%20plan%20France%20Relance%2C%20qui,et%20associations%2C%20collectivit%C3%A9s%20ou%20administrations.
[57] https://www.economie.gouv.fr/plan-de-relance/lancement-strategie-nationale-transition-economie-circulaire%23

Germany

Main national policy strategies:

A Circular Economy Roadmap for Germany: This roadmap, published on May 2021, is prepared by the Circular Economy Initiative Deutschland (CEID) on behalf of the Federal Ministry of Education and Research to shape a joint vision among stakeholders and propose a consistent framework of action towards circular economy in Germany. In a collaboration with nearly 130 experts from industry, academia, and civil society, CEID examined the European models of the circular economy and developed a roadmap for Germany based on a multi-stakeholder approach and suitable for its export-oriented economy.[58]

Circular Economy Act: In 2012, Germany revised its *Closed Substance Cycle and Waste Management Act* (*Kreislaufwirtschafts- und Abfallgesetz*) of 1996 and adopted its first *Circular Economy Act*[59] *(Kreislaufwirtschaftsgesetz, 'KrWG')*.[60] This Act featured product responsibility that requires "parties who develop, manufacture, process and treat, or sell products" to design products in a way that minimises waste production and ensures environmental-friendly recycling or disposal of after being used.[61]

Amendment to the Circular Economy Act: This amendment[62] came into force in 2020 in order to advance measures in the 2012 act. Most notably, this amendment expands the concept of product responsibility from the 2012 act to include *Duty of Care.*[63] This new element requires maximum maintenance of product usability, practically giving legal right to the government to detect and stop the alleged practice of online retailers to destroy returned products. Moreover, this act gives legal priority to recycled material over new ones in public procurement.[64]

National programmes and initiatives:

DigiRess: The *Digital Applications to Increase Resource Efficiency in Circular Production Processes* (*DigiRess*) is a funding programme run by the Federal Environment Ministry of Germany for the period 2022-2024 to support SMEs seeking transition to circular, more resource-efficient production through the use of the digital technologies. This programme has an overall EUR 8 m budget per year.[65]

ProgRess: The initial phase of the *German Circular Economy and Resource Efficiency Programme* (*ProgRess*) was adopted in 2012 and based on a four-year report and revise plan, *ProgRess II* and *ProgRess III* were passed by the German government in 2016 and 2020 respectively.

Budget:

No information identified

[58] https://www.circular-economy-initiative.de/circular-economy-in-germany
[59] https://germanlawarchive.iuscomp.org/?p=303
[60] https://www.oeko.de/en/research-consultancy/issues/resources-and-recycling/translate-to-englisch-deutschland-europa-global-kreislaufwirtschaft-fuer-eine-nachhaltigere-rohstoffverwendung
[61] https://www.globalcompliancenews.com/2020/03/08/germany-intends-to-introduce-a-duty-of-care-for-products/
[62] https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/kreislaufwirtschaftsgesetz_en_bf.pdf
[63] https://www.bmuv.de/themen/wasser-ressourcen-abfall/kreislaufwirtschaft/abfallpolitik/uebersicht-kreislaufwirtschaftsgesetz/die-obhutspflicht-im-kreislaufwirtschaftsgesetz
[64] https://www.bmuv.de/pressemitteilung/novelle-des-kreislaufwirtschaftsgesetzes-legt-grundlagen-fuer-weniger-abfall-und-mehr-recycling
[65] https://www.bmuv.de/pressemitteilung/bmuv-startet-neues-foerderprogramm-fuer-mehr-ressourceneffizienz-durch-digitale-anwendungen

Greece

Main national policy strategies:

National Strategy for Circular Economy: In December 2018, The Greek Ministry of Environment and Energy published the *National Strategy for the Circular Economy*. This document includes a comprehensive section '*Operational Action Plan 2018-2019'* that identifies the set of actions planned for the two-year period ahead. These actions come under four main themes: 1) Regulatory and Legislative reforms to support circular economy and address bureaucracy 2) Financing and financial incentives 3) Improvement of knowledge, of its management and exchange procedures and its interlinking with production, the economy and society 4) Support of circular economy and networking governance.[66]

National programmes and initiatives:

Greece's New Circular Economy Action Plan: This action plan builds on the 2018 national strategy and sets out an action plan towards the circular economy for a four-year period (2021-2025). This roadmap introduces 71 actions under five themes to accelerate Greece's transition to a circular economy. These themes are 1) sustainable production and industrial policy, e.g. ecological design, ecological certification, industrial symbiosis, tax exemptions, 2) sustainable consumption, e.g. promotion of green public procurement, repair services, reuse, 3) less waste with more value, e.g. financial programmes for prevention, institutional framework for prevention, 4) horizontal actions, e.g. national observatory, voluntary agreements, coordinating body, indicators, and 5) specific categories of products that must be addressed as a matter of priority, e.g. plastic products, batteries and vehicles. Moreover, plans for monitoring and funding the transition to the circular economy are also discussed.[67]

Budget:

No information identified

Hungary

Main national policy strategies:

In Hungary, a circular economy action plan is currently under preparation[68]. The Hungarian Circular Economy Platform together with the professional leadership of the Hungarian Business Council for Sustainable Development (BCSDH) and the Bay Zoltán NGO for Applied Research conducted a survey of the domestic potential of the circular economy in 2019 with the objective to identify the most important challenges and to map out solutions.

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[66] https://ypen.gov.gr/wp-content/uploads/2020/10/%CE%95%CE%B8%CE%BD%CE%B9%CE%BA%CE%AE-%CE%A3%CF%84%CF%81%CE%B1%CF%84%CE%B7%CE%B3%CE%B9%CE%BA%CE%AE-%CE%93%CE%B9%CE%B1-%CF%84%CE%B7%CE%BD-%CE%9A%CF%85%CE%BA%CE%BB%CE%B9%CE%BA%CE%AE-%CE%9F%CE%B9%CE%BA%CE%BF%CE%BD%CE%BF%CE%BC%CE%AF%CE%B1.pdf

[67] https://ypen.gov.gr/perivallon/kykliki-oikonomia/16052-2/

[68] https://kormany.hu/hirek/palkovics-egyre-inkabb-latszik-a-korforgasos-gazdasag-jelentosege

National programmes and initiatives:

The Circular Economy Platform was officially established in 2018 as an initiative of the Business Council for Sustainable Development in Hungary (BCSDH), the Embassy of the Kingdom of the Netherlands, and the Hungarian Ministry of Innovation and Technology[69]. The aim of the platform is to facilitate a paradigm shift and build a community of forward-thinking leaders by sharing business solutions.

The Circular Economy Technology Platform[70] (KGTP) was established at the University of Pannonia in Veszprém in 2022. Its main objectives are to accelerate the transition to a circular economy in Hungary and to place the country at the forefront of the use of circular economy technologies.

Budget:

The transition to a circular economy is one of the pillars of Hungary's Recovery and Resilience Plan with an estimated budget of EUR 590 m available for two priority areas: EUR 343 m will be devoted to the improvement of the waste management infrastructure, including collection, transportation and sorting capacities. EUR 247 m is devoted to the development of a smart, innovative and sustainable industry including a secondary raw material market[71].

Ireland

Main national policy strategies:

Whole of Government Circular Economy Strategy 2022-2023 'Living More, Using Less' is the first national circular economy strategy for Ireland. It aims to provide a policy framework for Ireland's transition to the circular economy, addressing economic, regulatory, and social barriers in this way and promote increased investments. The strategy sets the agenda for Sectoral Circular Economy Roadmaps to be developed for five resource intensive sectors notably: construction, transport, agri-food, consumer good, and procurement.[72]

Waste Action Plan for a Circular Economy is the updated version of Ireland's national waste policy that supports circularity and sustainability practices matching those of the Ireland Climate Action Plan and the European Green Deal.[73]

The Circular Economy Bill is an attempt to place the aforementioned policies on a statutory footing by defining the circular economy in the Irish domestic law and setting legal requirements. The bill has been signed by the President on 21 July 2022[74] and upon enactment, it will: 1) re-designate the current Irish Environment Fund as a Circular Economy Fund; 2) incentivise the use of reusables and recyclables; 3) introduce new segregation requirements for the commercial waste; 4) provide a range

[69] https://circulareconomy.europa.eu/platform/en/main-language/hungarian
[70] https://circularhungary.hu/
[71] https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility/recovery-and-resilience-plan-hungary_en
[72] https://www.gov.ie/en/publication/b542d-whole-of-government-circular-economy-strategy-2022-2023-living-more-using-less/
[73] https://www.gov.ie/en/publication/4221c-waste-action-plan-for-a-circular-economy/
[74] https://www.oireachtas.ie/en/bills/bill/2022/35/

of technologies to tackle illegal dumping and littering; 5) introduce prohibitions on exploration for and extraction of coal, lignite, and oil shale.[75]

National programmes and initiatives:

Circular Economy Programme 2021-2027: Ireland's Environmental Protection Agency (EPA) has prepared this programme as an action plan for the 2021-2027 period to materialise the goals of the government's circular economy strategy. The programme is structured around four pillars to foster the transition to a circular economy: 1) Advocacy, Insight, Data, and Coordination, 2) Innovation and Demonstration, 3) Delivering through Partnership, 4) Regulatory Framework for Circularity. Among the business and industry support plans in this programme, there is the 'Green Enterprise' innovation funding scheme under pillar 2, and revision of the Circuléire partnership[76] support scheme for circular manufacturing in SMEs and large companies under pillar 3.

Budget:

No information identified

Italy

Main national policy strategies:

Towards a Model of Circular Economy for Italy: This 'document of framework and strategic positioning'[18] was published in October 2017 after an extensive public consultation with over 300 representatives of public administrations, small, medium, and large companies, associations, consortia, certifying bodies, and private citizens. This document recognises regulatory amendment, economic instruments reform, awareness raising, and research promotion as the four necessary points of intervention for the Italian government to foster the transition to the circular economy. Moreover, the pivotal role of Industry 4.0 technologies is admitted in this strategic document and therefore, support for research and innovation to modernise the Italian industry and boost the circular economy transition is highlighted.[77]

National Strategy for Circular Economy: Adopted in June 2022, this is an updated version of the 2017 strategy with new objectives and measures to foster the transition to a circular economy in Italy by 2035. This strategy is developed with contributions from 100 different stakeholders, and it defines actions, objectives, and measures to boost the transition. The strategy introduced the following concepts: eco-design; reuse and repair; end of waste; critical raw materials and development of a secondary raw materials market; green public procurement and minimum environmental criteria; strategic industrial supply chains; industrial symbiosis; extended producer responsibility; and digitisation.[78]

National programmes and initiatives:

No information identified

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[75] https://www.gov.ie/en/press-release/e24d9-cabinet-approves-landmark-bill-that-will-introduce-world-leading-moves-to-reduce-waste-and-influence-behaviour/
[76] https://circuleire.ie/introducing-circuleires-2022-innovation-fund-awardees/
[77] https://circulareconomy.europa.eu/platform/sites/default/files/strategy_-_towards_a_model_eng_completo.pdf
[78] https://www.mite.gov.it/sites/default/files/archivio/allegati/economia_circolare/SEC_30092021_1.pdf

Budget:

EUR 5.27 bn has been allocated to the ‘Circular economy and sustainable agriculture’ under Mission 3 of the Italian *National Recovery and Resilience Plan* (PNNR) in November 2021. PNNR Mission 3 is for Green Revolution and Ecological Transition and amounts to EUR 59.33 bn.

Latvia

Main national policy strategies:

Circular Economy Strategy for Latvia: In October 2019, Latvia’s Ministry of Environmental Protection and Regional Development (VARAM) presented Latvia’s strategy for transition to circular economy as an informative report. This strategy was transformed into Latvia’s circular economy action plan for the period 2020-2027.

National programmes and initiatives:

Action Plan for the transition to circular economy 2020-2027: In September 2020, the cabinet of ministers of Latvia approved the country’s first circular economy action plan for the period 2020-2027. Thirty actions are introduced in the plan and for each action the responsible organisations, performance indicators, sources of funding, and deadlines are indicated. The actions include the ‘Promotion of the development of new generation technologies’ and ‘Development and improvement of support tools and provision of funding for innovation and research’ for the development and implementation of new material technologies. Funding is provided from existing resources under the EU support programmes and the government budget.[79]

Budget:

No information identified

Lithuania

Main national policy strategies:

Lithuania's strategic documents have prioritised the development of the circular economy in the National Progress Plan for 2021-2030 with the objective to reorient industry to a circular economy and promote the development of advanced technologies and innovation.[80] Lithuania has not published any strategies or action plans on the circular economy. However, its recent recovery plan includes actions such as “to increase the circularity of the economy and contribute to the decrease of emissions in consumption-based and production-based processes, Lithuania’s government chose to use the national resilience and recovery plan for investing in the technologies and infrastructures, which would decrease the need for energy imports and improve the material footprint through the digitalisation of assets and processes.”[81]

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[79] https://likumi.lv/ta/id/317168-par-ricibas-planu-parejai-uz-aprites-ekonomiku-20202027-gadam
[80] https://lic.lt/wp-content/uploads/2021/01/Ziedines-ekonomikos-pletros-priemones-ir-sprendimai.pdf
[81] https://china-cee.eu/2021/07/07/lithuania-social-briefing-lithuanias-green-economy-plan-gets-the-highest-mark-from-brussels/

National programmes and initiatives:

No information identified

Budget:

No information identified

Luxembourg

Main national policy strategies:

Circular Economy Strategy Luxembourg: Luxembourg's Circular Economy Strategy was published in February 2021 with the aim to aligning relevant stakeholders with a common vision and coordinate activities across sectors. The document defines the strategy, the governance model and key sectoral action points.

In June 2021, Luxembourg's Ministry of Economics presented the '*Roadmap for A Competitive and Sustainable Economy 2025*' focusing on accelerating digitalisation, facilitating the transition to a circular economy, developing strategic, resilient value chains and fostering a safe, trusted data economy.[82] The roadmap is found on six building blocks, the second one of which is 'Driving the digitally enabled circular economy transition'.[83]

National programmes and initiatives:

The circular economy strategy outlines actions in three categories: regulations and standards, financial aspects, and knowledge creation and management. Industry actions include the development of a data management scheme for circular value chains, or the supporting the development of shared infrastructure and services in economic activity areas.[84] Sectors that are specifically addressed include construction, education and training, finance, food and biomaterial, industry, and retail.

Budget:

No information identified

Malta

Main national policy strategies:

The Circular Economy Strategy Vision 2020-2030: Malta's Ministry of Environment, Sustainable Development and Climate Change has set up an agency called 'Circular Economy Malta' (CE Malta) since 2018 with the objective to foster and facilitate Malta's transition to the circular economy.[85] The Circular Economy Strategy Vision 2020-2030 is both a mission/vision statement for CE Malta agency as well a strategic document for Malta to lay out its approach, objectives, and instruments within the 2021-2030 period to foster the transition.[86]

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[82] https://tradeandinvest.lu/news/new-luxembourg-roadmap-for-a-competitive-and-sustainable-economy/
[83] https://meco.gouvernement.lu/fr/publications/strategie/strategie-ons-wirtschaft.html
[84] https://economie-circulaire.public.lu/en/publications/circular-strategy.html
[85] https://cemalta.gov.mt/wp-content/uploads/2022/02/S.L-595.28-EN-Establishment-of-Agency.pdf
[86] https://cemalta.gov.mt/wp-content/uploads/2021/09/email-version-fin.pdf

National programmes and initiatives:

Circular Economy Malta (CE Malta)[87] supports actions that foster a business environment whereby producers are responsible for the products placed on the market, from placement on market until the end of product life.

Budget:

No information identified

Netherlands

Main national policy strategies:

Government-wide programme for a Circular Dutch Economy by 2050: The Dutch government released its circular economy strategy in September 2016 with an interim goal for 2030 to reduce the primary raw material usage by half. The strategy prioritises five areas: biomass and food, plastics, the manufacturing industry, construction sector and consumer goods. The ultimate objective of this strategy is to achieve a circular economy in the Netherlands by 2050.[88]

Transition agendas: Following the five priority sectors highlighted in the government programme for 2050, as well as a *Raw Material Agreement* with 180 parties in 2017,[89] the Dutch government published separate transition agendas for each of the five sectors to specify government interventions that can accelerate the transition to a circular economy. These interventions broadly fit under fostering legalisation and regulations, intelligent market incentives, financing, knowledge and innovation, and international cooperation.[90]

National programmes and initiatives:

National Science Agency (NWO) research programmes annually allocate funds for academia-industry collaborative R&I projects with a budget of EUR 0.5 to 10 m per project. Multiple projects that got funded address circular economy innovations in various industries, as well as interdisciplinary topics, social, behavioural and business aspects.

Circular Economy Implementation Programme: In 2019, the Dutch government presented a comprehensive circular economy implementation programme for the period 2019-2023. This implementation programme features concrete actions and projects. The measures in this programme follow the same five-agenda division introduced in the previous policy documents with ten cross-cutting themes such as: 1) Producer responsibility (EPR); 2) Legalisation and regulation; 3) Circular design; 4) Circular procurement; 5) Market stimuli; 6) Funding instruments; 7) Monitoring, knowledge, and innovation, behaviour and communication, education and the labour market; 8) International efforts.

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[87] https://cemalta.gov.mt/

[88] https://circulareconomy.europa.eu/platform/en/strategies/circular-economy-netherlands-2050

[89] https://voorlichting.rijksoverheid.nl/documenten/rapporten/2017/01/24/grondstoffenakkoord-intentieovereenkomst-om-te-komen-tot-transitieagenda-s-voor-de-circulaire-economie

[90] https://www.government.nl/topics/circular-economy/accelerating-the-transition-to-a-circular-economy

Netherlands Circular Accelerator[91] is a business support network created by VNO-NCW / MKB Nederland, their regional affiliates and the Ministry of Infrastructure and Water. An assessment of the programme progress is conducted every year and the results and recommendations are published. These reports can lead to updates in the implementation programme[92][93].

Budget:

In 2020, EUR 217.5 m was allocated to circular economy projects (EUR 50 m of which is Horizon 2020 contribution) and EUR 55.1 m tax incentives given to businesses.[94]

Poland

Main national policy strategies:

Roadmap towards the Transition to the Circular Economy: The first consideration of the 'Circular Economy' in the Polish government dates back to 2016, when an inter-ministerial committee for the Circular Economy was set up. In 2019, the government of Poland adopted its circular economy roadmap after an extensive public consultation and work of over 200 social and economic partners, as well as representatives of central and local government administration.

National programmes and initiatives:

The Polish circular economy roadmap defined 41 actions mainly concerning awareness raising, information circulation systems and regulation.[95]

Budget:

There is no separate fund dedicated to implementation of the roadmap, hence existing budget and funding programmes are supposed to be used for the implementation of the circular economy roadmap. As written in the roadmap, circular economy will be reflected in investments and actions aimed at innovation, research and development. Financial support for circular economy actions can be supported under the Horizon 2020 programme. The implementation of circular economy actions can also be financed from other sources of public sector funding such as environmental fees. In the future, if legislative changes are introduced to the waste management system, financing can be provided from the deposit systems within the environmental protection system.[47]

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[91] https://voorlichting.rijksoverheid.nl/documenten/rapporten/2019/02/08/uitvoeringsprogramma-2019-2023 ; English translation available: https://hollandcircularhotspot.nl/wp-content/uploads/2019/09/Circular-Economy-Implementation-Programme-2019-2023.pdf

[92] https://www.rijksoverheid.nl/documenten/rapporten/2020/09/25/uitvoeringsprogramma-2020-2023

[93] https://www.rijksoverheid.nl/documenten/kamerstukken/2021/10/18/aanbieding-uitvoeringsprogramma-circulaire-economie-2021-2023

[94] https://www.rvo.nl/sites/default/files/2022-06/Monitoring%20transitie%20naar%20een%20circulaire%20economie%20op%20basis%20van%20overheidsondersteuning%202015-2020_0.pdf

[95] https://circulareconomy.europa.eu/platform/sites/default/files/md_goz_final_en_r4_4.pdf

Portugal

Main national policy strategies:

Portugal's 2030 strategy comes with a section on '*Transition to Circular Economy'* under the Climate Transition and Resource Sustainability agenda.[96] Portugal 2030 Strategy is a framework of actions in a partnership agreement between Portugal and the European Commission.

Portugal has published a national '*Waste Management Plan Horizon 2030'* in line with circular economy principles.

Leading The Transition: A circular economy action plan for Portugal 2017-2020 was published in December 2017. The Portuguese Council of Ministers approved PAEC – Portugal's 2017-2020 action plan for a transition to circular economy.[97] The action plan takes an innovative approach by dividing the actions into a tri-level macro/meso/micro representing the national, sectoral, and regional levels of operation.

National programmes and initiatives:

The Portuguese circular economy action plan was comprised of seven actions, including the definition and support of the research and innovation agenda to support the transition to a circular economy. The sectoral level focused on Tourism, Textile and Footwear, and Retail and Logistics, as the three key sectors in Portugal's economy, for being materials intensive, export-oriented, with significant consumer impact. Lastly, the regional level actions come under three themes to identify opportunities and support the establishment of networks for industrial symbiosis, circular cities, and circular businesses.[98] The action plan comes with an analysis of available sources of funding under the current EU and national funding programmes. There are no records of an action plan or any exclusive circular economy roadmaps for the period after 2020.

Budget:

No information identified

Romania

Main national policy strategies:

As yet, there are no records of a national circular economy strategy or roadmap available for Romania. However, the Institute for Research in Circular Economy and Environment 'Ernest Lupan' – IRCEM, has been in charge of a project titled *'Romania's strategy for the transition to a circular economy (ROCES) 2020-2030'* to support the development of a national strategy for Romania. Within this project, more than 10 workshops and conferences were held in 2019 to involve different stakeholders in the discussion about Romania's actions within 2020-2030 for a successful transition to a circular economy.

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[96] https://www.portugal.gov.pt/download-ficheiros/ficheiro.aspx?v=%3D%3DBQAAAB%2BLCAAAAAAABAAzNDC3NAEAkBRcpAUAAAA%3D
[97] https://dre.pt/dre/detalhe/resolucao-conselho-ministros/190-a-2017-114337039
[98] https://eco.nomia.pt/contents/ficheiros/paec-en-version-4.pdf

National programmes and initiatives:

No information identified

Budget:

No information identified

Slovakia

Main national policy strategies:

Slovakia does not have a circular economy strategy or action plan, however, the Slovak Environmental Strategy has recognised the importance of the transition to a circular economy and established the *Circular Slovakia Platform* in October 2019. This platform aims to increase discussion between the public and the private sector about opportunities and barriers in the circular transition.[99]

The circular economy has been addressed in other policy documents. The '*Strategy of the Environmental Policy of the Slovak Republic until 2030*' adopted in 2019 defines the transition to circular economy as one of its priorities.[100] A circular economy roadmap has been also outlined for Slovakia by a recent OECD[101] report published in 2022 that provides an analysis and a set of key elements for development. In this report, Slovakia has suggested three priority areas notably the horizontal area of sustainable consumption and production, with a specific focus on economic instruments; the construction sector; and the food and bio-waste value chain.

National programmes and initiatives:

No information identified

Budget:

No information identified

Slovenia

Main national policy strategies:

Slovenia developed its national roadmap towards the circular economy[102] in 2018 (among the first in Central Eastern Europe) that sets the path to become a circular economy front runner. Following a multi-stakeholder consultation, it identified four priority areas such as the food system, forests, manufacturing industry and mobility. The roadmap has adopted a system approach and acts along several dimensions including entrepreneurship, policy and education. Circular economy objectives are also included in other key national documents such as the Vision for Slovenia in 2050, the Slovenian Development Strategy 2030, Slovenia's Smart Specialisation Strategy, and the long-term climate strategy. The roadmap is based on various inputs and discussions conducted during 7 meetings in 12 regions of Slovenia, 7 interactive

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[99] https://circulareconomy.europa.eu/platform/en/dialogue/existing-eu-platforms/circular-slovakia
[100] https://www.minzp.sk/en/areas/green-circular-economy/
[101] https://www.oecd.org/fr/publications/closing-the-loop-in-the-slovak-republic-acadd43a-en.htm
[102] https://circulareconomy.europa.eu/platform/sites/default/files/roadmap_towards_the_circular_economy_in_slovenia.pdf

workshops, a review of 100 good practices and 19 structured interviews with key stakeholders from government departments, the economy, interest groups and experts from individual fields.

National programmes and initiatives:

The strategies, which address green economy are the *Slovenian Industrial Strategy 2030*, and the draft of *Smart Specialisation Strategy*. There are also reform programmes incorporated in the Slovenian recovery and resilience plan.

Slovenia promotes innovative policy initiatives of transformative change.[103] For example, the Slovenia Innovation Hub in cooperation with the Technology Park Ljubljana supports circular economy minded start-ups with training and coaching.

Slovenia has been implementing waste management measures and was recognised for its efforts in separate waste collection. Slovenia collaborates with the EIT Climate-KIC and participates in the 'Deep Demonstrations of Circular, Regenerative Economies programme[104]' launched in 2021. The project aims to introduce circularity by activating a coordinated portfolio of innovation actions in key economic sectors and selected value chains.

Budget:

Slovenia's national recovery and resilience plan has a separate component to promote circular economy through financial investments and regulatory reforms. The so-called 'circular economy' component sets measures to promote material productivity, eco-innovation, and the link to waste management and support schemes through approximately EUR 48 m of grant, worth nearly two percent of the total NRRP budget of Slovenia.[105] Public support to green and circular economy in Slovenia, will gradually intensify through different measures for research, development and innovation, investments in better and new production, digitalisation and support for SME to use green technology solutions.

Spain

Main national policy strategies:

ESPAÑA CIRCULAR 2030: Spain's ten-year strategy for transition to a circular economy was adopted in June 2020. The strategy promotes ten guiding principles: Protection of the environment, Maximising product life cycle, Waste hierarchy, Reduction of food waste, Production efficiency, Sustainable consumption, Communication and awareness, Employment for circular economy, Promoting public and corporate research and innovation, Standard indicators adoption. Overall, the strategy comes with concrete goals for 2030, including a 30% reduction of domestic material consumption in relation to the national GDP (reference year 2010) and a 15% waste reduction (reference year 2010).[106]

National programmes and initiatives:

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[103] https://circulareconomy.leeds.ac.uk/wp-content/uploads/sites/35/2021/04/Circular-Slovenia_final.pdf
[104] https://www.climate-kic.org/programmes/deep-demonstrations/
[105] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021SC0184
[106] https://circulareconomy.europa.eu/platform/sites/default/files/espana_circular_2030_executive_summary_en.pdf

First Circular Economy Action Plan: This action plan adopted in May 2021 upon requirements in the *ESPAÑA CIRCULAR 2030*, comprises 116 actions identified by the *Spanish Ministry for the Ecological Transition and the Demographic Challenge* (*MITECO*) for the period 2021-2023. A total budget of EUR 1529 m is dedicated to this action plan, focusing on eight main areas: 1) Production, 2) Consumption, 3) Waste management, 4) Secondary raw materials 5) Water reuse and purification, 6) Awareness and participation, 7) Research, innovation and competitiveness, and 8) Employment and training. In particular, the research, innovation & competitiveness line with 9 actions aims to promote R&D activities related to circular economy and facilitate the dissemination of the results. Action 7.1.8 of this line highlights the forthcoming renewal of wind turbines in Spain and the problem of recycling the blades.[107]

Budget:

EUR 1529 m for 2021-2023.

Sweden

Main national policy strategies:

Circular Economy – Strategy for the transition in Sweden: In July 2020, the Swedish Ministry of the Environment and the Ministry of Enterprise and Innovation published this document to lay out the Swedish government's strategy for a transition to a circular economy in the post-pandemic period. This strategy establishes four focus areas: 1) Circular economy through sustainable production and product design 2) Circular economy through sustainable ways of consuming and using materials, products and services 3) Circular economy through non-toxic and circular material cycles 4) Circular economy as a driving force for the business sector and other actors through measures to promote innovation and circular business models.[108]

Circular Economy – Action Plan for the transition in Sweden: Following the circular economy strategy outlined above, the Swedish government announced an action plan for the transition to a circular economy in 2022. This action plan builds on the four focus areas established in the strategic document and presents the policy instruments and measures that the Swedish government intends to use in order to achieve the environmental goals in the 2030 Agenda. The government plans to develop specific national strategies for electrification,[109] water,[110] and bioeconomy,[111] to complement the 'Circular Economy Action Plan'.[112]

The Swedish EPA's roadmap for the sustainable use of plastics: As the head of the Swedish National Plastic Coordination, the Swedish Environment Protection Agency (EPA) has prepared this roadmap to provide an overall picture of the common priorities and needs for the Sweden's transition to sustainable use of plastics. This roadmap is

[107] https://www.miteco.gob.es/es/prensa/ultimas-noticias/el-gobierno-aprueba-el-i-plan-de-acci%C3%B3n-de-econom%C3%ADa-circular-con-un-presupuesto-de-1.529-millones-de-euros/tcm:30-526709
[108] https://www.government.se/information-material/2020/11/circular-economy--strategy-for-the-transition-in-sweden/
[109] https://www.regeringen.se/regeringens-politik/transportsektorn-elektrifieras/el-4/
[110] https://www.regeringen.se/pressmeddelanden/2021/02/en-efterfragad-strategi-for-effektiv-och-hallbar-vattenhushallning/
[111] https://www.regeringen.se/rattsliga-dokument/kommittedirektiv/2022/06/dir.-202277/
[112] https://www.regeringen.se/informationsmaterial/2021/01/cirkular-ekonomi---handlingsplan-for-omstallning-av-sverige/

developed in line with the Swedish Circular Economy Action Plan for the period 2021-2025 and is supposed to be revised and updated by the end of this period.[113]

National programmes and initiatives:

In Sweden's 2021 budget bill,[114] circular economy has received a dedicated line of investment with SEK 150 million for 2021, SEK 140 million for 2022 and SEK 10 million for 2023. However, the 2022 budget bill[115] does not contain any records specifically mentioning the circular economy.

Budget:

SEK 150 million for 2021 (approx. EUR 13.8 m).

Norway

Main national policy strategies:

Norway has a strategy for developing a green, circular economy since June 2021.[116] The vision and overall objectives formulated in the strategy make it clear that the Norwegian Government does not consider the transition to a circular economy to be a goal in itself. Instead, it is viewed as a process that will contribute to value creation and sustainability and at the same time result in progress towards Norway's climate and environmental policy targets. This may include inter alia a step-by-step introduction of recovery of at least 65% of textile residue form waste and re-use by 2035 and an Action Plan for more climate-friendly public procurement, etc.

National programmes and initiatives:

Norway's national action plan focuses, among other ecosystems, on the construction and building sector. Greenhouse gas emissions from buildings themselves are low, but the construction sector generates large indirect emissions, for example as a result of using construction products. It also generates large quantities of waste. The most important way of increasing circularity in the sector is to maintain buildings and other structures and lengthen their lifetime. A larger proportion of building materials should also be returned to the cycle for re-use. The government wants to promote such re-use. The action plan puts a focus on: (i) The use of standards as tools for the transition to a circular economy; (ii) The 'Start Off' programme aims to support the development of circular solutions in cooperation between public and private actors; (iii) Competence raising project; (iv) Digital solutions for a more circular economy.

There is public R&I support available in Norway administered by the State Innovation Support Agency including the following measures: 1) the 'Green Platform' which supports R&D-projects aimed at value creation at different TRLs; 2) the 'Environmental Technology programme' which supports pilots and demo projects in the

[113] https://www.naturvardsverket.se/amnesomraden/plast/hallbar-plastanvandning/naturvardsverkets-fardplan-for-en-hallbar-plastanvandning/

[114] https://www.government.se/information-material/2020/09/from-the-budget-bill-for-2021-budget-statement/

[115] https://www.government.se/press-releases/2021/09/budget-bill-for-2022-a-stronger-and-more-sustainable-sweden-after-the-pandemic/

[116] https://www.regjeringen.no/contentassets/a116f209e493471bb26c81cf645152a3/kld_strategi_sirkularokonomi_sammendrag_eng_0507.pdf and the full document is available in Norwegian here: https://www.regjeringen.no/no/dokumenter/nasjonal-strategi-for-ein-gron-sirkular-okonomi/id2861253/

field of environmental technology; 3) the ‘Cluster Programme’; 4) The Innovation Contracts scheme; 5) Innovation loans to private businesses; 6) Support for bio-economy projects.

Budget: No information identified

ANNEX 5 | WORKSHOPS AND CONSULTATIONS FOR THE ERA INDUSTRIAL TECHNOLOGY ROADMAP FOR CIRCULAR TECHNOLOGIES AND BUSINESS MODELS IN TEXTILE, CONSTRUCTION AND ENERGY-INTENSIVE INDUSTRIES

Focus Group Meeting for scoping the circular industrial technology roadmap, 10 September 2021/ summary conclusions

This report summarises the discussions held during the first focus group organised as part of the scoping for a Circular Industrial Technologies Roadmap. The focus group was attended by 45 participants. The aim of the focus group was to present the initiative and discuss the preliminary list of technologies defined in the scoping paper, as well as criteria for the selection of technologies in order to refine the list.

First plenary

Welcome & introduction was done by Peter Dröll, Director, Prosperity Directorate, DG Research & Innovation. The key messages of his presentation were the following:

With the industrial technology roadmaps, the European Commission is aiming at increasing joint R&I investments and accelerating the uptake of relevant technologies. The process will include designing roadmaps with R&I investment agendas with favourable framework conditions, completing and validating evidence with EU Member States, industry representatives, RTOs and universities. The stakeholder engagement and collaboration is key in this process. Besides industries, RTOs and research actors, the EU Horizon Partnerships, EIC, EIT, sub-groups of the ERA Forum for Transition will be consulted in order to align with their priority challenges and agendas.

Doris Schröcker, Head of Unit, Industrial Research, Innovation and Investment Agendas, DG Research & Innovation explained the scope, purpose of the Circular Industrial Technologies Roadmap, as well as process that it will include, including the role of the present Focus Group meeting

Energy-Intensive Industries – breakout session

Moderated by Morgane Veillet and Asel Doranova, Technopolis Group

General remarks

Technology scoping:

- Listed technologies in overall are relevant, but some remarks have been done in each technology group (presented under separate section below)
- It was suggested to add **cement** industry as a separate sector. However, it makes sense to coordinate with the scope of the roadmap on Low-Carbon Technologies (LCT) that is being developed in parallel exercise.
- It was suggested to include **glass industries** sharing similar challenges with ceramic industries.

- The roadmap should distinguish between carbon-intensive and circular technologies. There are at times **overlaps between** the two or too much of a focus on the former.

Cross-cutting technologies/approaches:

- In general, **industrial symbiosis** between various industries and value chains should be addressed.
- Technology design aspects should also be addressed as part of the roadmap. This links more broadly to the **design** for zero pollution, design circularity, which materials to use, etc.

Criteria for selection of technology:

- TRL is one of the important indicators, but not only.
- Potential for solution of given problem (e.g. how efficiently, better, the technology resolves the problem) – this criteria needs to be defined and made measurable
- Consider possible cross-media / rebound effects that could arise from deploying certain technologies. The question should always be whether the technology could have a negative impact.
- Cost of technology is an important factor for industries. Cost-efficiency could also be more comparative measure.

Remarks on Chemicals

- An important remark was made regarding what is meant with “industrial ecosystems”. The chemical sector finds itself part of many different ecosystems. How should the scope for circularity be considered, from waste value chains or from a cradle-to-cradle approach? -
- An additional challenge that has not been explicitly mentioned concerns the current problem of fugitive and diffuse emissions which are not channelled, especially in the polymer sector. Electrification of chemical processing (of furnaces, for example) is also a big issue and of a cross-cutting nature (for ceramics too).
- In general, some keywords and statements need refinement and structuring. For instance, the sectors ambition with CCU is to reuse rather than store. Regarding circular feedstock issues, there is a lot to say here as well.
- Some refining is needed regarding the problem statements too. For the priority technologies, the following document should be consulted: SIRA http://www.suschem.org/highlights/suschem-sira-2019-technology-priorities-towards-2030-for-a-better-future-of-europe, as well as further consultation with the representatives of the chemical industry
- Do we see bio refineries included as part of the chemicals industries solutions or not? Bio-based industrial technologies are in some cases seen as more sustainable alternatives to the traditional chemical production processes. Further analysis and considerations needed.

- It was also noted that hydrogen technology is one possibility to reduce the greenhouse gas emissions, this however could be better addressed in the LCT roadmap.
- Some technology groups that are missing for the chemical industry include design for circularity, digital enabling technologies.
- The Cefic will be in touch to provide some more information on the sector.

Remarks on Ceramics

- For ceramics, it is very important to differentiate between the products when looking at circular solutions. For example, bricks, clay blocks, pavers, roof tiles can be reused as such whereas refractories or tableware can be recycled.
- Consider further extend ceramics to include glass industries that share similar challenges.

Remarks on Steel and other metals

- The EU has limited mining of iron ore and steel production from iron ore; most steel in the EU is produced from scrap metals
- Advanced steels are indeed a very good innovation; however, we must be careful with cross-media effects with potentially negative impacts. A lot of energy is needed to develop such high-strength steels.
- Steel is highly recyclable but the issue that needs to be tackled is the combination of steel-copper which prevents effective steel recycling. These techniques are needed to improve circularity.
- Another focus should be on the by-products of steel which are produced (dust, sludge, etc) and potentially can be an input in other industries (Waste-to-value):
    - Response from the consultants: Some solutions were identified while pursuing the literary review but these could perhaps be considered **value from by-products rather than waste**. E.g. ArcelorMittal (as well as other companies) already works on processes that will help reuse black furnace slag and waste gases from various stages in the steelmaking process (e.g cement or fertiliser). They are piloted technology that reuses waste gases from steelmaking (CO, CO2) into bio-ethanol with microbial/biological processes.
    - There are policy limitations to some innovations for reusing by-products. E.g: slag is not allowed as a fertiliser in all countries; slag may not be considered a good aggregate in some markets with productive quarrying, etc .
    - Another article pointed to the recovery of value-added products (e.g. rare earths) from steel slag. There numerous studies on the waste to value topic in steel/metal industries (e.g. : “Waste to value in steel-making”, Advances in Molten Slags, Fluxes, and Salts: Proceedings of the 10th International Conference on Molten Slags, Fluxes and Salts 2016)

- Mining and steel are two separate things and the former is of less relevance for the scope of the study. Mixtures in technologies should be refined.

Construction – breakout session

Moderated by Dominik Beckers, Technopolis Group

Technology scoping*:*

Recycling construction materials into high quality products:

- Participants raised the point that the presentation made by Technopolis seems to indicate that the construction industry "is already there" (i.e. circular technologies are already largely mainstreamed in the construction sector). However, participants do not believe this to be the case. While there are indeed several technologies to recycle materials and waste into concrete products, larger-scale solutions are still mostly lacking.
- The obstacles are many: only a small amount of building materials can be recycled, and only when the quantity and characteristics of each concrete material are exactly known (which is not always the case). Some materials' characteristics do not allow them to be fully recycled either.
- Renewable materials can be a big part of the solution; and the easiest way to reduce landfill waste is to use more renewable materials. Participants argued for this point to be reflected better in the roadmap.
- Concerning the technology groups that would be considered to get renewable materials into construction: Productivity growth in the construction sector has largely stagnated in the past decades. Hence, innovations that would boost productivity have been scarce and have not had any larger impact. Yet, plenty of potential applications were identified: e.g. in off-side production, building materials, pre-constructions, or the development of engineered wood products.

Hardware challenge VS the digital challenge.

- If one can make the distinction between digital and hardware challenges, the digital side should be prioritised in the line of action. This does not mean that digital solutions and approaches are more important, however, they are a prerequisite for a fully functioning ecosystem and form the backbone of circular technologies in the construction sector. Digital approaches are needed for integration which, in turn, is a major structural dimension of a circular economy. Ultimately, handling both the hardware and the digital at the same time, needs to be done most efficiently and seamlessly. At the same time, room needs to be given to citizens to be involved more closely.
- The digital side is also perceived to be an integral part of material processing and making them fit for circular economy. An efficient digital interface enables registering all steps, properties etc. about any material at any given time, which is an inevitable source of information particularly for the deconstruction processes of buildings. This, in turn, also translates into new design practices of buildings. If one talks about synergies with other sectors, one needs to look at Supplementary Cement Materials and low-carbon technologies, too.

Logistics

- The supply chain also has to be expanded towards logistical aspects in the construction process. Here, plenty of potential that has not been tapped into yet is evident. Hence, logistics should be considered when proposing technologies for the circular economy roadmap. Looking at where (either locally or in another site) and how the materials will be transported and recycled is an important element.

Technologies and building stocks

- Technologies that can be retro-fitted to building stocks (i.e. already existing structures) exhibit large potential. This is believed to be effective as it will have an immediate and measurable impact on the circular economy. At the same time, learning from existing stock will help in avoiding making the same mistakes that were made in the past. Understanding how technologies can be used in later stages of a building's lifecycle translates into intelligence for future design processes.

Cross-cutting technologies/approaches

- Plenty of horizontal or cross-cutting decision are already on the table. These are particularly evident in digital technologies (e.g. AI, Big Data, Blockchain). It was claimed that there is ample learning potential from other sectors, particularly from mechanical engineering, where digital solutions are already more mainstreamed and integrated than in the construction industry. There also already several applications of AI in the construction sector, which itself was inspired by yet different sectors.
- Pre-fabrication in itself is a cross-cutting process. Here, intelligence can be drawn from other industries such as the automobile sector or robotics. Building modules are now easily transported. Moreover, there is plenty of efficiency to be gained in land-controlled environments or 3D printing. There could be more use of robotics and manufacturing overall.
- The ceramic sector was taken as an example, in that it has a significant impact on, and similarities with, the construction ecosystem. Hence, when thinking about the circular economy, one also needs to think about sectors that share similarities and are adjacent (like steel or ceramic).

Selection Criteria

Environmental Friendliness – as a general criteria: Circular technologies also need to be understood from the point of view of overall environmental benefit, not only circulation of materials. Hence, technologies need to be approached from a wider, more holistic stance where aspects such pollution cannot be sacrificed for greater circularity.

As an overarching point, it was noted that legislation needs to enable circular processes and transition from the currently predominant linear doctrine. The European Commission is believed to be in a leading role in this context.

Textile – breakout session

Moderated by Margaux Le Gallou, Technopolis Group

The discussions focused on the type of textiles that are produced or recycled in Europe. Clothing was less of a focus than anticipated, and there was a **preference for discussing technical textile**.

Technology scoping

Recycling techniques

- Need to develop research on the different applications of textile waste within and outside the textile industry
- Need further development of both mechanical and chemical recycling.
- Textiles/fibres sorting technologies are important: technologies are currently under development (no technology name mentioned). These technologies enable the identification of textile, without the need for labels.
- Decolorization (remove of pigments) is an important issue for recycling and need innovative technologies
- Mono materials facilitate recycling of textiles/garments and therefore innovation/design towards more mono-materials based textiles should be promoted.

Quality control:

- It is a point on which there is still much progress to be made: measurement technologies can be used. Digital tool will help. Specially to have information on the quality of raw material, which is crucial.
- New labels and classification system, more accurate and tighter must be created, with clauses and sous-clauses to know what one is buying.
- Sorting processes need improvement (label, classification, identification of fibres). Passports have been mentioned as a possible help, as well as QR codes on labels.

Production process

- Reflection must be made on plasma technologies to prepare the fibre.
- Ozone technologies are also available.
- Substitution in chemicals (alternative chemicals) is also a good idea but is not always possible, especially when we do not have information all the properties of the chemicals.
- In dyeing it is possible to use nano-chemicals, or to use less chemicals. Liposomes can also be used in the dyeing process.
- Water-free dying might not be as promising as it was hoped for
- Design and fibre blends to simplify recycling. Complex blends are an issue for recycling (see mono materials point above)

Cross-cutting technologies/approaches

- Chemical technologies for production of fibres or recycling are same as for several other sectors (plastics, polymers, etc.)
- Digital technologies are important for textile (and apparel industry/sector). They are used in many sectors, but normally targeted to support specific process, application, service.
- Industrial symbiosis possibilities can link different industries. e.g. recycled textile is often used in other sectors (e.g. construction)

Selection criteria

- Potential of the technologies is a key criterion. First, we must look what technologies have the biggest potential in environment.
- Find upcoming technologies that are at low TRL (Technology Readiness Level) but with strong potential

Second plenary - Debrief from the breakout sessions

<u>Cross-cutting technologies/approaches</u>

- Digital technologies are identified to be a horizontal technology that can facilitate circularity in all industries. They can help both in monitoring and optimising the existing processes, resource use, waste minimisation, but also in providing new solution like 3D printing in construction, or introduction of digital product passport to improve transparency about products/materials, facilitate recycling, etc.
- Industrial symbiosis – is a cross-cutting approach that has a potential in most/all industries, facilitates waste-to-value principles, diverts waste from landfilling and promotes recycling opportunities
- Resource and energy efficiency measures – are incremental improvements but can offer big saving and waste minimisation potential. Often they are seen as low-hanging fruit in reaching reducing material/water/energy consumption and contribute to circularity and sustainability objectives
- Design for circularity is also a cross-cutting approach that can help to transform industries and make them more or fully circular. Design of products, materials, processes should integrate possibility for more efficient and easier recycling, remanufacturing, reuse, repair or extend durability.
- Biotechnologies offer based solutions/ materials that are often seen as more sustainable substitute to fossil based materials or products with low/zero/negative carbon footprint. They also perform better in term of harmful emissions. Biotechnology and biobased industries, including biorefineries can offer more sustainable inputs to many traditional industries
- Waste collection, sorting and recycling technologies are often mentioned as key enabling technologies for circular economy. The analysis shows that many industries are lacking well developed systems and technologies for collection, sorting and recycling that prevent achieving maximum circularity in these industries.

Technology Selection Criteria

- Technology Readiness Level – is an important criteria. Higher TRL is seen as one offering faster market penetration potential. However, some promising technologies are in their early TRL stage and still need to be supported.
- Environmental problem reduction potential is an important feature for selection of the most promising technology. Examples for could range from GHG emission reduction, to other air emissions to water pollution, to high health impact chemicals. A consistent, well defined and measurable criteria needs to be applied here.
- Avoidance of cross-media / rebound effects is an criteria that also addressed environmental impact, but it would require to analyse it deeper, by looking into the potential long-term negative impacts that new technologies can have.
- Cost / economic performance of the technology – one of the basic criteria that helps to identify (among alternatives) and promote those circular technologies that are more cost effective, thus more attractive to industries and therefore have better opportunities to market take up

Next steps in the process of building the roadmap

- The present Focus Group meeting is a part of the Technology Scoping exercise and the Evidence building phase
- The Scoping will be enriched by further interviews and desk research based on the feedback collected now. SME survey will also feed the analysis.
- The following consultation processes will provide further insight for way forward and defines pathways to be included in the Roadmap Policy workshop in 2022 will help refine them collectively with a wider set of stakeholders, collect further feedback
- In the following processes the present participants will be invited, but the consultation group will be bigger.
- The JRC, especially the teams working with the IED related environmental best available technologies related reference documents (BREFS) will be closely consulted
- RTOs from Member States will be important stakeholders too and should be well engaged
- Some workshops initially indicated in the planning are likely to be merged. The stakeholder will be informed and invited well in advance.

Stakeholder Workshop, 31.05-01.06.2022 / Key messages from the stakeholder discussions

As part of the ERA Circular Industrial Technologies Roadmap, the workshop aimed to contribute to the assessment of the technologies identified as essential in the transformation of industries towards a circular economy in the EU. More specifically, the workshop validated the results of the technology assessment, it discussed the role of business models, and it identified the barriers and enabling framework conditions to put circular industrial technologies on the market and reach wide diffusion.

The results of the workshop are based on the active discussion of 80 workshop participants with a background from industry, research and technology organisations and policymakers.

Peter Dröll, Prosperity Director at DG Research & Innovation of the European Commission, welcomed the participants and opened the workshop.

1st Day Technology assessment validation – Energy intensive industries

Chemicals

Technology assessment results:

- The **assessment of technology readiness levels should depend on the target product being considered**. In some cases, it is misleading to have high and low TLRs. For example, improved separation technologies, in particular the upcoming generation, are far from achieving TRL 9. A wider debate is needed on how to evaluate the TRL range being presented. A **broader TRL range** was recommended.
- It is important to **consider technology readiness level in the value chain as a whole**. Often, certain production technologies are quite advanced (e.g., homogeneous and heterogonous catalysis), but there are factors that make them less competitive in the whole value chain.
- **Fermentation of CO2 is a missing technology**: heterogenous and homogeneous catalysis can convert chemicals in the recycling process in order to have fermentation. It will help to convert into materials.
- **Minor adjustments were made on the Mural for the TRL assessment**. For material sourcing, one participant considers leaching/depolymerisation, biotechnological recycling and solvolysis to be of lower TRL (3 rather than respectively 7-8, 6 and 4-6). Similarly, another participant considers that technologies for the implementation of digital twins are TRL3 rather than TRL7-8.

Circular and market potential:

- Based on the Mural assessment, there is **generally a correlation between the circularity and market potential of technologies**. There are a few exceptions however:
    - Regeneration of spent solvents is considered by one participant to have high circularity potential but low market potential. Similarly, chemical reactions, digital twins and digital processes in plant engineering is considered to offer medium circularity potential but low market potential.

- When looking at **circular performance, the impact of GHG emissions is not always recognised**. The economic potential of technologies will depend on policies and frameworks.
- **Digital technologies present higher market potential than what has been illustrated so far**. Startup attractiveness conclusion of 'none' seems unrealistic for AI and ML. These technologies represent a growing field and are likely to spread into several subfields, like improved separation technologies. One participant further argued that AI-enabled solutions offer attractive prospects, as they can help us play with numerous materials, manage the complexity that comes with materials and harmful chemicals.

Steel:

Technology assessment results:

- **Zinc recovery is a technology that deserves more attention**. There is a big market potential for zinc as it is recovering a lot from minerals. Zinc recovery from electric blast furnace should be included in the roadmap. However, there is a negative environmental impact as these processes are using coal to obtain zinc recovery. Moving from coal to gas, natural gas, hydrogen and electricity is the priority to achieve truly circular and low-carbon processes.
- **Scrap technologies are key for achieving circular steel**, in particular for removing the copper from the scrap. It was suggested by a participant to include a point on **copper removal in scrap**.
- **Waste gases in steel industry** are rich in carbon monoxide and **can be valorised through industrial symbiosis processes**. Waste gas can be valorised as a fuel but zinc can also be recovered. Some industrial symbiosis projects are trying to convert those gases into valuable chemicals: this is an illustration of the cross section between decarbonization and circular economy.
- Looking at alternative energies, **using waste plastic as a fuel in the blast furnace process** is developing. It is already happening in Italy. Heat recovery is at the frontier of the low-carbon and circular roadmap.
- New slag treatment could be envisioned in particularly for secondary metallurgy slag and SS steel grade.
- **Participants amended the assessment made for several technologies on the Mural**.
    - The use of carbon-fibre-reinforced polymers in EAF should be extended to polymers from waste plastic. These are already in use in BF and EAF.
    - Zinc is a valuable material that can be recovered from steelmaking fire dust. Several reducing technologies, in addition to filter dust residue, can also be considered to recover metal fraction form metal oxide and mineral fraction (as slag).
    - Plasma reactors can also be used to reduce metal oxide waste.
    - Different types of slag can be considered (see REACH classification)
    - The Hisarna technology can be removed as the company working on it (Tata Steel) is no longer going through with the project.

Circular and market potential:

- Overall, based on the Mural, there seems to be a correlation between high circularity potential and market potential for technologies. For residue valorisation and content recovery, Recodust for Fe and Zn recovery from BOF dust both showed strong circularity and market potential. This was also the case for digitalisation tools for monitoring, waste plastic gasification for syngas production, slag utilisation strategies and scrapyard management using sensors and machine learning.
- **Steel-marking processes vary and so do the subsequent residual valorisation processes**. Current steel-making processes use 58% iron one, 42% electric arc. These processes currently produce the slag. Slag coming from blast furnace techniques is sold to the cement industry. Slag from the electric arc furnace route is used for road construction. Slag which comes from secondary metallurgy is still a problem, but the main point is that **residuals vary**. Slag handling and treatment produced by new routes are different to old routes. **New markets have to be investigated and explore new waste routes**, as new energies are used for production processes produce new slags.

Ceramics:

Technology assessment results:

- The **diversity of products** should be taken into account in the assessment of technologies.
- All ceramic industry has **sustainability problems regarding the sourcing of raw materials**.
- It has to be kept in mind that as a result of the increasing energy costs, it might be more expensive to crush and reuse than buying a new material.
- **Full circle sustainability analysis** across industries is needed to compare the different recycling technologies and value chains with each other.
- The Process for Planet Partnership indicated the importance of **industrial symbiosis**. Their latest roadmap relies on the partnership priorities and technology areas.
- The ceramic industry is **resistant to change** and usually operates with low margins. The supply chain problems in China should be taken into account.
- About resistance to change, **non-technological solutions** should be better detailed.
- In the case of chemicals, **product-service systems** are relevant, but these business models are less obvious for steel and ceramics.

Final conclusion:

- The list of technologies has been confirmed to be **overall representative**
- Nevertheless, **several additional technologies were mentioned and should be added to the roadmap**. These include zinc recovery from electric blast furnace, new slag treatment for secondary metallurgy slag and SS steel grade and copper removal from scrap for steel. For chemicals, fermentation of CO2 was mentioned

- **Some technologies can be grouped together**, such as for example the leaching process or the zinc recovery process for chemicals, but it is important to still keep a level of granularity in the form of the long list of technologies
- There is generally a **positive correlation between the circular potential and the market potential of technologies**, save for some specific cases
- The **market potential of digital technologies** should be further emphasised in the roadmap
- The link with the carbon roadmap comes mainly from the energy being supplied to conduct technological processes. Green and alternative energy sources need to be better associated to processes
- The **circularity potential of technologies should be considered in the value chain as a whole**. Geographic aspects also need to be considered as the chemical, steel and ceramic markets are global and circularity will not be achieved by looking at Europe alone.

Additional shared documents to take into account:

https://cerameunie.eu/media/zyqdwwwp/ceramic-roadmap-to-2050.pdf

Technology assessment validation - Construction

Comments:

- Alternative material sourcing in particular urban mining related technologies should be indicated at a higher TRL level (6-9). Some of these **technologies are already on the market and proven**.
- The barrier behind material/recycling technologies is often **standards**. Cement and concrete with construction demolition waste are possible as soon as the standards allow them (by end of 2022).
- Under alternative materials, the **reuse of concrete elements rather than recycling in granulates** could be highlighted.
- **BIM represents a huge opportunity to enable circular and sustainable construction**, although the maturity in many sectors is quite low or at extremely varying levels. Time required for developing simple BIM models of end-of-life building is still a barrier. These technologies should be indicated with a lower TRL level 6-7.
- **Materials identification and automatic object recognition** is at low TRL.
- **Design for disassembly is crucial** and it is not really tackled in building's and product's design. To this end, more training for professionals is needed. It also encounters difficulties due to standardization VS architecture. However, an important barrier is that the scarcity of circular products is linked to their certification.
- Difference should be made between **component assembly and the design process**.
- **Off-site construction has a high circularity potential** but currently is not fully developed yet.

- ‘Classification as waste‘ generates a complexity in terms of permissions in particular for new technologies upcycling waste.
- **Recycling, reuse and disassembly technologies** should be more clearly differentiated and described in the roadmap.
- **Robotics** has a huge potential for disassembly.
- For disassembly, the report should highlight the ‘Lean to Cradle’ methodology (eg. from Construcía/EIG).
- For product reuse after its first life, there is a platform called upcycle that aims at compiling all the product info as well as any process applied to it, so it is available once it can be recycled.
- It is often difficult to reuse, assess, source and it is better to adopt an approach of ‘**Construct less’;** for instance, via space sharing, better functionality, economy of scale. The circular economy is not only about closing the cycle, but it is also about **long life of buildings and the use of less natural resources.**

Final conclusion:

- The list of technologies and their assessment was validated keeping in mind the changes suggested as above.
- Technology groups with the highest circularity potential but also market opportunity include alternative material sourcing and recycling.

Technology assessment validation - Textiles

Comments:

- **Digital passport** is an important tool to identify the chemical structure and the nature of the fabric. This can be important during the whole value chain and therefore the circularity potential can be rated higher. E.g. in the case of blends or cross-waves of textiles, one needs to know exactly what the components are. It is easier to identify the approach to separate them into different (chemical) compositions. However, one **needs to be sure that the data we put in the passport is exhaustive** and correct.
- The **TRL level of recycling dye/ pigments in wastewater can be put at a higher level**, this is already a common process. It can, however, differ widely per technology, as there are also newer technologies for recycling dye/pigments that do have low TRL’s.
- For collaborative consumption models, it was noted that **sharing and renting are good methods** to keep fabric in circulation, which implies a high circular potential. It is economically feasible to invest more in the production of the fabric so that it is feasible to use more sustainable production technologies and better materials.
- Some remarks were made regarding **leasing and rental models**: a medium-high market potential was suggested following the experience that many companies tried and failed in the past years. Furthermore, it was noted that the related transport costs need to be considered, e.g. the transport of one dress from another country to a customer. Leasing and rental models must be differentiated from consumption business models in the analysis.

- The **opinions regarding virtual fabric sourcing were divided**. On the one hand, it was argued that the potential is high, as it makes it easier for SMEs to select sustainable fabrics by making it possible to calculate the circularity index in the garment and design process. On the other hand, it was argued that the potential is low, as textile fairs are there for a reason: in most cases you need to feel and touch the fabric to select it.
- The opinions regarding **design for sustainability also varied**. On the one hand, there could be much potential if the durability is improved. On the other hand, if the product is only used a few times, material durability does not matter: “a fashion type that is somewhere in a wardrobe, can never be sustainable". Also, it was said that we tend to over-engineer with fancy and expensive textiles. Textiles need to be durable, but not if the design and production relies on a lot of resources. Putting a threshold on the quality of products was suggested.
- **Chemical recycling** was pointed out as being important although difficult. The production and preparing stages are very important, as they can avoid waste in the first place.
- **Better and less expensive technologies would be needed to detect chemicals when sorting** products for reuse. There is a debate if it is feasible to do this sorting.
- On the retail side, **second-hand selling should be better highlighted**. The market potential could be medium high but the circularity potential is high.

Final conclusion:

- Digital collaborative models circularity potential needs to be adjusted
- For the digital passport add one more star on the assessment of circularity
- The TRL level of recycling dye/pigments in waste water can be low or high depending on the technology.
- Look more into the potential of virtual fabric sourcing, as opinions are divided.
- Add second-hand selling on the retail side.

2nd Day Framework conditions

Regulatory framework conditions

There is an **issue of overregulation and overspecification** in certain fields that prevent circular industrial solutions to materialise. **Regulations should ensure that a market can be developed around circular industrial technologies.** In the case of the steel industry, there are several problems with the current regulations. The revised Renewable Energy Directive (REDII) and the delegated act on RFNBOs and RCFs pose for instance clear problems. Although the steel and chemical industries developed technologies that help the reduction of CO2, but the regulation in place limits market deployment. In order to install this technology, the delegated act requests that the carbon footprint reduction is at 70% compared to fossils and there is an obligation to use green electricity. These hurdles are unmanageable. In China this requirement is not imposed, and the market is developing fast. DG RTD, CLIMA and ENV could become better aligned regarding the various regulations.

More guidance is needed how to comply with new regulations. In the case of the textiles industry, the EU strategy is quite recent, and the sector is afraid of how to learn to navigate under the new rules. One needs more training in order to better understand the regulations: what will happen when and what is exactly asked from the companies.

Regulations and policies should better incentivise the use of circular solutions and pull the demand side of circular technologies. Although, there are ongoing initiatives, but more needs to be done. A good example that was pointed out is the incentives put in place earlier on to foster the use of halogen-free flame retardants.

There is a competition among industries to use more sustainable materials. Speeding up the use of circular raw materials such as bio-derived materials in the chemicals industries is hindered by the availability of this feedstock and high prices. The fuel industry is incentivised and supported by various EU directives to use bio-based materials. There is no such playing field in the chemicals industry.

In the case of the construction industry, **zero-waste policies should be put in place in the demolition of buildings**. More incentives to use recycled materials should be designed.

In the case of **ceramics**, despite the legislations there is rather a slowdown towards circularity. The **barriers are related to the naming and classification of waste and quantification methods** of environmental impact. The raw materials are relatively cheap, and the incentives are not too strong to use recycled materials.

The **definition of waste as a secondary raw material is not always clear** and poses barriers for specific countries.

The issue how **specific regulations are taken up and implemented across EU Member States** makes the transition towards the circular economy uneven given the facts that the level of ambitions among countries are different.

Permissions and authorisation to roll out new technologies at an industrial scale are often hindered by current requirements. The setting up such factories should be treated under industrial legislations and not under waste management rules. It takes 2-3 years to obtain the permission to perform this activity. **Regulations are needed that defines waste as raw materials.**

Startups face specific difficulties to comply with regulations that needs to be addressed.

Non-regulatory framework conditions

During this session, it was acknowledged that it is important to **adopt a life cycle perspective during the whole value chain**. To ensure that a product can be recycled at the end of its lifecycle, the workforce involved in the design phase should have the knowledge to understand how the materials that are part of a product are disassembled and re-introduced in the supply chain.

Trainings and education strategies should look at different levels of education, including **lifelong learning**.

Given that digital technologies will play an enabling role for the integration of many of the identified circular technologies, the development of **digital skills** associated to these technologies should be prioritise and addressed.

Sharing good practices and success stories on how innovative circular technologies have been taken up and used by the industry would be beneficial to better understand the business benefits.

There is a need for **new governance mechanisms** that are in line with the application of a life cycle approach. The holistic nature of this perspective requires channels that ensure a structured dialogue and communication between the different segments of the value chain.

In order to **track materials and products**, data should be collected and made available for predictions.

Industrial symbiosis is a model that should be further promoted.

There is a need for risk sharing measures and more testbeds especially for the chemical sector.

Skills related to financial models have to be developed and specifically addressed by skills programmes.

Standards connected to the quality of products are another area for consideration.

The attention was drawn to the needs of small and medium-sized enterprises that are usually less well equipped financially.

Business models

One of the general conclusions of this session was that although many of the circular industrial technologies are mature, there are still important barriers in terms of **proving the business case and finding an appropriate business model** that ensures the long-term uptake and diffusion of these technologies.

More incentives should be in place that motivate industrial companies to adopt new technologies. Examples include **repair or reuse bonus**.

The business model is strongly linked to **service innovation**, where technological solutions are offered in a form of licensing agreement or other service models.

In order to facilitate market uptake of circular design or recycling technologies, traditional industrial firms in particular the large firms need to adjust their organisational structure, otherwise there is a risk of no real positive change.

Digital technologies and the use of data is one of the important drivers behind the creation of new circular business models. **AI technologies have a high potential** to underpin new service models and help companies to save costs and at the same time reduce the use of resources and the production of waste. Nevertheless, there are more work to do to prove the technology in industrial applications.

A key question how the **value can be transferred from the investors that initiate a circular solution pr product and final beneficiaries that will use the product** and hopefully benefit for instance through evolutive models.

Reverse logistics is a model that has been highlighted and needs more promotion. Large manufacturers can plan right from the start with reclamation of raw materials, refurbishment, and reselling of items. Extended responsibility of the producer is key in this aspect.

In relation to transparency, the European '**digital product passport'** should be considered that is an initiative that is urgently needed to allow for the industries to monitor the flow and origin of products, but while this initiative is rolled out there is a need for interim solutions.

Stakeholder Workshop on investment needs assessment, 6 July 2022/ Key messages from the discussion

The workshop was organised as part of the ERA Circular Industrial Technologies Roadmap that aims to foster the circularity of three industrial ecosystems: energy-intensive industries (steel, chemicals, ceramics), construction, and textile. The objective of the workshop was to **gather expert insights about the estimated investment needs that are necessary to transform the industries in focus according to the principles of the circular economy.**

Introductory presentations

Peter Dröll, (Director, European Commission DG RTD) welcomed the participants and opened the workshop. He drew the attention how the current geopolitical context makes the transition towards an energy and resource-efficient industry urgent. He also stressed that the EU aspires to be the first climate neutral continent and hence reaching the EU climate targets are more critical than ever. Against this backdrop, the EU circular industrial technologies roadmap addresses three industries and aims at mobilising stakeholders to act fast and accelerate the circular economy transformation.

Doris Schröcker (head of unit, European Commission) continued by presenting the team behind the ERA circular roadmap and the more specific objectives.

Vilius Stančiauskas (research director, PPMI) presented their research and landscaping exercise to capture R&D investments based on Orbis data. In addition, they had leveraged Technote data and investment announcements that companies make on their websites. They identified key circular technologies and found 8,900 companies with a circular industrial technology profile. They found that 7% of construction, 3.8% of energy intensive industries and 2.9% of textiles companies analysed had invested in circular industry technologies. The median investment amount was similar in the case of textiles and energy intensive industries, notably close to €13 m.

Kincsö Izsak and Asel Doranova (Technopolis Group) presented the project history and the methodology behind the estimation of investment needs. The analysis was based on existing assessments of public-private partnerships, desk research, interviews, a Delphi survey and review of related national and private programmes in the focus of this particular roadmap. The Delphi exercise that was implemented under the current study collected experts' views on the funding needs for possible R&I activities towards TRL9 on each circular technology listed for each industrial ecosystem. The move towards a circular economy is an integral part of the transition pathway for these ecosystems and requires a long-term constant investment into various pillars of the transformation process including new technologies, new business models, circular infrastructure, skills, new governance model and social change.

Key discussion points

Participants were asked to share their comments both on the online Mural board and during the discussion. Some of the participants stated that they need to further consult their members to be able to provide proper feedback. It was also stressed that it is very difficult to come up with any estimates due to the complexity of the subject. Key points highlighted were the following:

- It was clarified that the reuse of concrete in cement production was taken into account as part of the construction roadmap.
- It is important to consider the impact of policy incentives and how the national and regional circular policies influence the uptake of circular economy related technologies and business models. This would be an important aspect to analyse within the roadmap. For instance, the ETS Emission Trading System is a key driver behind circularity. The roadmap does not include any impact assessment of policies as such, but it has a section that reviews the current regulatory framework and summarise the opinion of the consulted stakeholders on existing legislations that can drive circularity.
- Clarifications were given how the investment needs for the design of more efficient kilns had been estimated that was based on the Delphi exercise.
- Investments are necessary not just to make products more circular but also to remain competitive internationally.
- The 'Go to market strategy' of circular ventures is very expensive and should be estimated around €50 m.
- In the case of textiles, the design for sustainability stage would require at least 4 highly innovative companies from TRL1-6 to support with €20 m each.
- In order to make at least 4-5 companies to grow in the field of alternative textiles materials and become competitive one needs an investment of at least €60 m.
- It was highlighted that there is a need to invest in new textile materials recognition technologies beyond near infrared (NIR).
- The dissemination of circular business models within industry would need a support of €10-20 m.
- In the case of energy intensive industries, there is a need for technologies to reduce water consumption and reuse heat.
- Further investments are needed for upskilling and reskilling of staff using the new circular technologies.
- The identification of new business models where scale is not the crucial efficiency parameter would need to be addressed.
- There is a need to promote recycled products on the market which need further investments.

The workshop was closed by the final words of Doris Schröcker from the European Commission.

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This document includes the annexes to the ERA industrial technology roadmap for circular technologies in the textile, construction and energy-intensive industries. It contains five documents prepared by Technopolis: a methodology of technology assessment, tables of circular industrial technologies, a small and medium-size enterprises survey conducted for the roadmap, an overview of national investments and programmes of EU Member States and Norway related to circular industry/economy, and a report of the workshops and consultations that took place in the context of the preparation of the roadmap.

Research and Innovation policy

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