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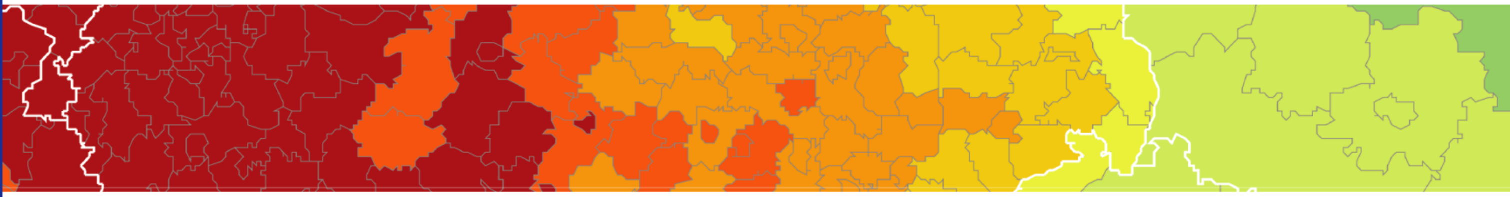

CIRCTER – Circular Economy and Territorial Consequences

Applied Research

Final Report

Annex 7

A system's perspective on the circular economy

Version 09/05/2019

Final Report

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Abbreviations

B2B	business-to-business
B2C	Business to Consumer
C2C	Consumer to Consumer
CBM	Circular Business Model
CDC	Caisse des dépôts et consignations
CE	Circular Economy
CEAP	Circular Economy Action Plan
CER	European Remanufacturing Council
CLD	Causal Loop Diagram
DE	Domestic Extraction
DMC	Domestic Material Consumption
DMI	Direct Material Input
EC	European Commission
EEA	European Environmental Agency
EMAS	European Monitoring and Audit Scheme
EMF	Ellen MacArthur Foundation
EPR	Extended Producer Responsibility
ERDF	European Regional Development Fund
ESPON	European Territorial Observatory Network
EU	European Union
GDP	Gross Domestic Product
GPP	Green Public Procurement
GWR	Geographically Weighted Regression
JRC	Joint Research Centre
IS	Industrial Symbiosis
LMM	Last Minute Market
MBT	Mechanical-Biological Treatment
MFA	Material Flow Analysis
MS	Member States
MSW	Municipal Solid Waste
NACE	Nomenclature of Economic Activities
NUTS	Nomenclature of Territorial Units for Statistics
OLS	Ordinary Least Squares/Linear Regression
OVAM	Public Waste Agency of Flanders
P2B	Peer-to-business
P2P	Peer-to-peer
PPP	Purchasing Power Parity
RMC	Raw Material Consumption
RMI	Raw Material Input
ResCoM	Resource Conservative Manufacturing
SME	Small and Medium Enterprises
RIS3	Regional Innovation Strategies for Smart Specialisation
ToR	Terms of Reference
WEEE	Waste from Electrical and Electronic Equipment

1 Methodological note

1.1 What is a CLD?

The main tool used for the exploration of the systemic behaviour of the circular economy is called Causal Loop Diagram (CLD), or system map. A CLD is a map of the system analysed, or, better, a way to explore and represent the interconnections between the key indicators in the analysed sector or system (Probst & Bassi, 2014). As indicated by John Sterman, "*A causal diagram consists of variables connected by arrows denoting the causal influences among the variables. The important feedback loops are also identified in the diagram. Variables are related by causal links, shown by arrows. Link polarities describe the structure of the system. They do not describe the behavior of the variables. That is, they describe what would happen if there were a change. They do not describe what actually happens. Rather, it tells you what would happen if the variable were to change.*" (Sterman, 2000)

Practically, the creation of a CLD supports (a) the selection of relevant indicators, (b) the determination of causality among these variables, and (c) the identification of critical drivers of change (e.g. feedback loops, or circular relations) that are the primary responsible for the past, present and future behaviour (or trends) of the system.

The use of CLDs is proposed because (i) when developed to integrate knowledge and through a group model building exercise, a CLD elicits knowledge and creates a shared understanding of the key drivers of change of a system, and hence on the possible outcomes of policy implementation across sectors and actors; (ii) CLDs highlight the boundaries of the analysis, supporting the inclusion of social, economic and environmental indicators in a single framework of analysis to fully capture the benefits of a CE; (iii) by visualising how variables in the system are interconnected, CLDs allow all stakeholders to reach a basic-to-advanced knowledge of the systemic properties of the issues analysed.

1.2 How is a CLD built?

The creation of a CLD follows a systematic step-by-step approach. It is important to start with a blank screen and add one (possibly key) indicator identified as representing the problem to solve or the opportunity to realize (i.e. an indicator of performance of the system that indicates whether the problem is intensifying and/or whether we are moving closer to the desired state of the system). The next step consists in the identification (and inclusion in the diagram) of the variables representing the causes of the problem and available indicators to measure them. These additional variables have to be added one by one, and a link should be established and represented between the variable representing the cause and the effect(s). This step includes the determination of the polarity of this causal relation, which can be positive or negative[1]. The process continues with the identification and inclusion in the diagram of the variables representing the cause of the cause, and so on. The creation of the CLD, and specifically the identification of causal relations and their polarity is informed by qualitative and quantitative information from (1) databases (e.g. time series), (2) peer-reviewed papers, (3) reports and (4) expert opinion. Note that even if no well-defined indicator exists for a variable, the variable should still be included in the diagram to make it more comprehensive and better reflect reality.

Once the diagram is complete, feedback loops are identified. 'Feedback is a process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself' (Roberts, Andersen, Deal, Garet, & Shaffer, 1983). Feedback loops are responsible for the behaviour of the system, and often, even if several loops are found, only two or three dominate the system in terms of strength. Specifically, feedback loops can be classified as positive or negative. Positive (or reinforcing) feedback loops amplify change and are typically identified by a 'R' notation, while negative (or balancing) counter and reduce change are identified by a 'B' notation. As a result, when the system shows exponential growth, the dominant feedback loops are reinforcing loops. When a diminishing trend, or constant state of the system are observed, a balancing loop is dominant. Naturally, loop dominance can change over time, generating S-shaped trends for instance.

1.3 How are the CLDs for CIRCTER created?

Several versions of the general CLD have been created. The starting point was the review of relevant literature and the collection and analysis of relevant data. As an example, the CLD includes all nine circular strategies presented in the circular economy Policy Report authored by Putting et al. in 2017 (Potting, Hekkert, Worrell, & Hanemaaijer, Circular economy: Measuring innovation in the product chain, 2017), as well as the policy assessment framework presented in Potting et al. (2018). Also, the CLD has been inspired by the literature collected by the territorial analysis task (see Annex 1), and particularly by the conceptualizations proposed by the Ellen MacArthur Foundation (2015), and a number of academic works, including Kalmykova et al. (2018) and Vis et al. (2016)

Building on the existing body of work in the circular economy field, the CLD includes elements of (1) production and (2) consumption. It shows how interventions on (1) the production side

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1 A causal link from variable A to variable B is positive if a change in A produces a change in B in the same direction; a causal link from variable A to variable B is negative if a change in A produces a change in B in the opposite direction.

can reduce costs and increase economic competitiveness, while improving resilience and lowering environmental impacts. It also shows how better economic performance leads to more consumption and hence production, possibly offsetting the gains made initially. As a result, the CLD also includes interventions on (2) consumption, which complement those analysed on the production side. Here it includes repair, refurbishing, remanufacturing or reduced consumption (refuse), which lead to lasting reduction in resource use and environmental impacts. On the other hand, reduced production may lead to lower employment, which is compensated by the increase in jobs in repair and recycling among other options. In summary, the CLD was built to integrate knowledge across disciplines and domains.

It is crucial that a CLD is also built on solid and verifiable information. The variables and causal relations included in the CLD have been confirmed and validated using available literature and (qualitative and quantitative) data. Specifically, this validation has taken place with direct support from other tasks concerning the quantitative verification of causal relations (e.g. through statistics), and the qualitative validation of feedback loops and local dynamics. Policies were added, and their outcomes analysed, with support from the case studies, for which CLDs were also developed. The case studies have directly contributed to the validation of local dynamics, and the interpretation of the strength of selected feedback loops (e.g. the main driver for change in Maribor was the well-being of its citizens, while economic performance and competiveness were the primary motives for the creation of a circular economy strategy in central Germany and Basque Country).

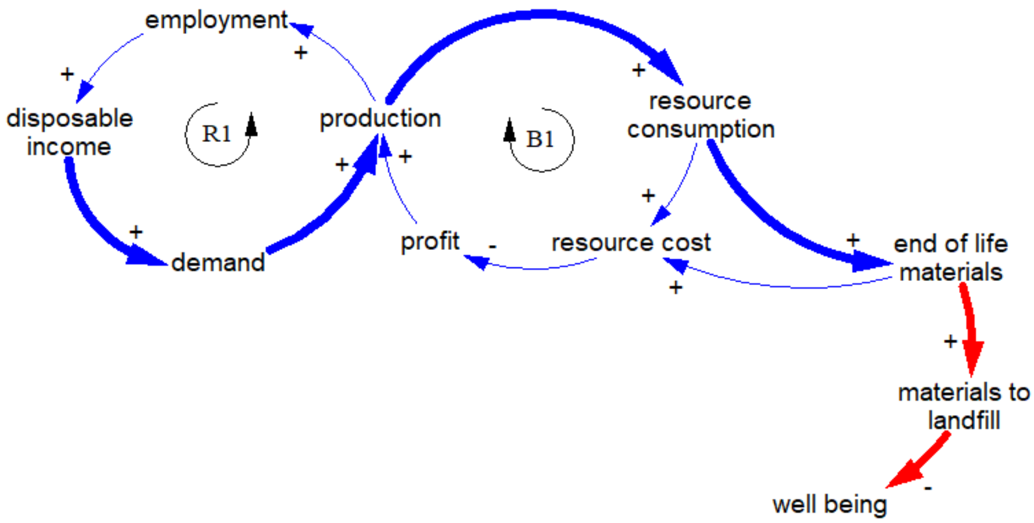
2 What territorial narrative emerges from the CIRCTER systems' analysis

The objective of the circular economy is to shift the current economic production setup from a linear to a closed-loop and more sustainable system.

1. With the current production setup we transition from demand, to production to resource management.

Under the current economic paradigm, the growth of income drives the demand for goods and services, which influences production; production in turn leads to resource consumption, resulting in the generation of products and end-of-life materials, as well as pollution (e.g. air and water); end-of-life materials are then accumulated in landfills, which negatively impact well-being (e.g. through air, water and noise pollution). This process is illustrated in the Causal Loop Diagram (CLD) in Figure 2-1. The casual relations that represent the current linear approach are presented using thick blue arrows, while the negative impacts of having end-of-life materials are highlighted with red arrows.

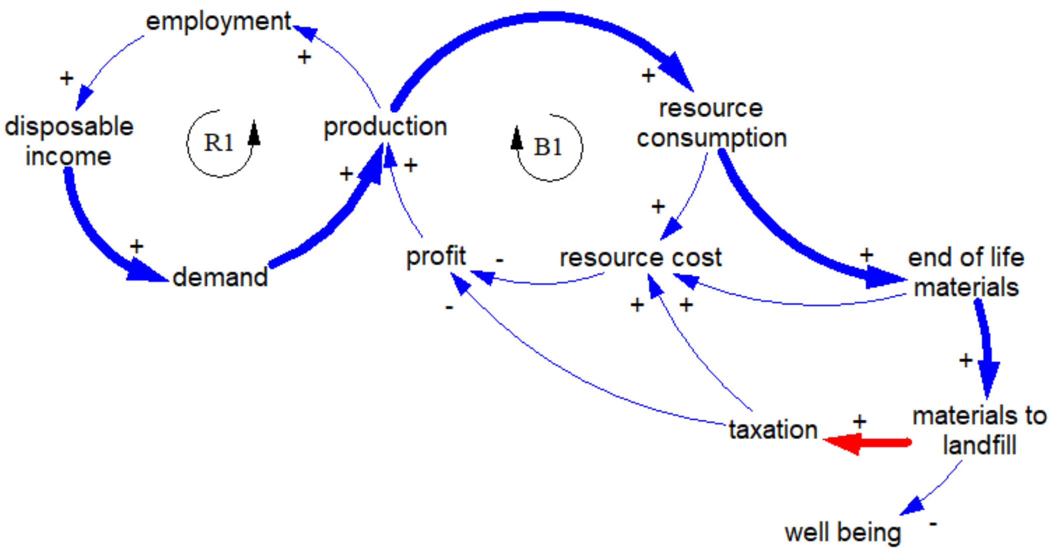
Figure 2-1: Simplified CLD of the current production system



2. If materials end up in landfills we require higher taxation to cover growing costs, and face negative impacts on well-being

The accumulation of materials in landfills and the resulting negative side effects has led to increasing taxation and waste management regulations to cope the increasing costs of managing landfills and abating negative side effects. These impacts are illustrated by the red arrow in Figure 2-2.

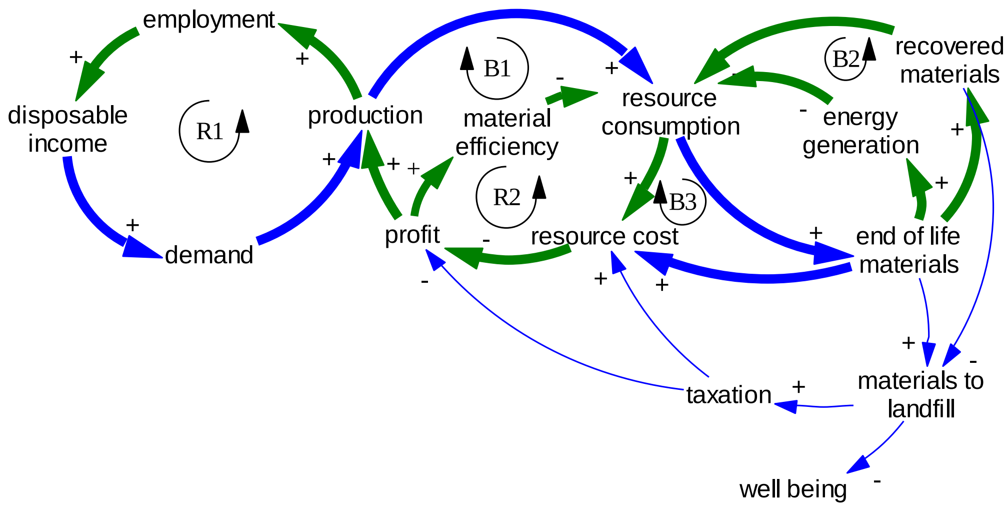
Figure 2-2: Taxation as response to negative waste management impacts



3. Material recycling and reusing allows to reduce resource consumption, which reduces costs and allows production to increase, leading to higher demand and resource consumption. Practically, it closes the cycle and it is thought to allow for "infinite" production and consumption that drives the economic system beyond the coping capacity of global ecosystems. This is because it weakens the balancing loop (B1) and, as a result, it strengthens the reinforcing loop (R1).

Waste management practices, such as waste separation and recycling, allow to reduce the consumption of virgin materials through the recovery of and recirculation of already existing raw materials. The recovery and use of end-of-life materials has multiple benefits, such as reducing costs and emissions in the production process and increasing material availability. One of the most prominent examples is the aluminium industry. The recycling process of aluminium saves up to 95% of the energy required to produce primary aluminium with only minor impacts on the structural properties of the final material. On the other hand, the increased availability of materials and the reduced cost of production can unlock growth potential. While this is positive for economic growth, it leads to higher production, which ultimately results in higher resource consumption and extraction. While closing the loop for production, recycling and the reuse of materials does not necessarily curb extraction.

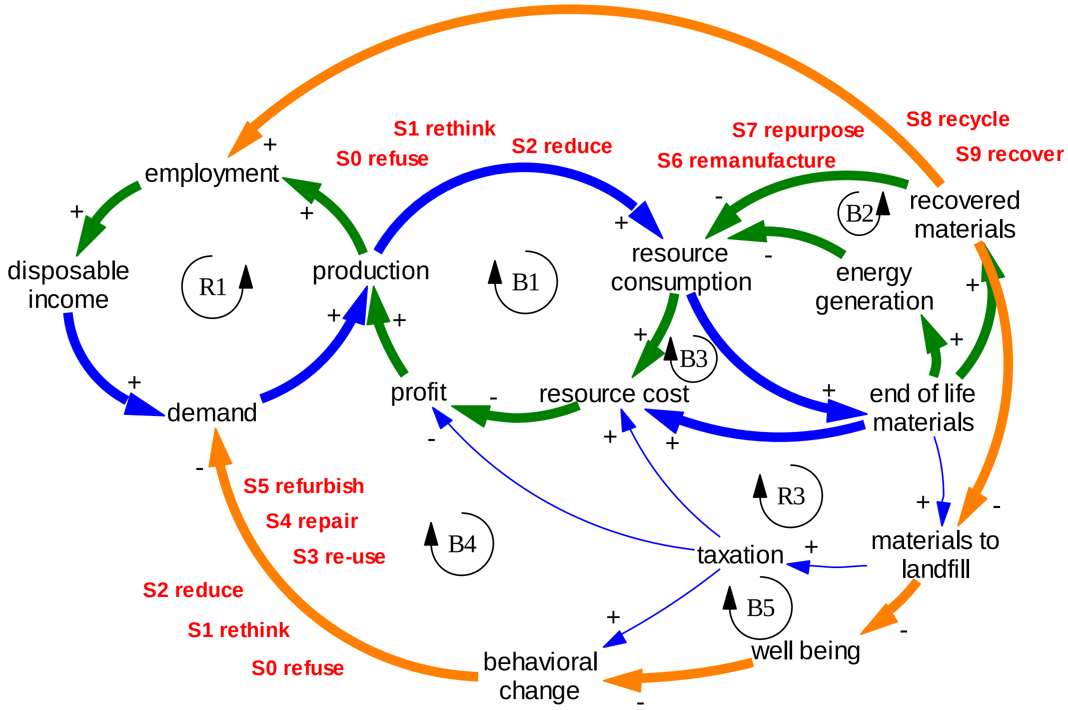
Figure 2-3: Introducing recycling in the current production process (green arrows highlight the impact of CE interventions)



As illustrated in Figure 2-3 by means of the green arrows, the recovery of materials reduces consumption below the baseline value and curbs resource costs, which benefits profits and incentivizes additional production and demand. At the same time, material recovery reduces the materials sent to landfill and hence reduces the need for taxation (further stimulating demand and production) and improves well-being.

4. However, full circularity can only be achieved when consumption is curbed, through system change. Strategies for system change involve both (1) industries and (2) citizens. Economic opportunities emerge through maintenance and repair, refurbishing, repurposing and remanufacturing, but also through rethinking, refusing, re-using. This makes full use of the three dimensions of circularity: (i) demand, (ii) production and (iii) resource management.

Figure 2-4: Integrated CLD including strategies targeting businesses and citizen[2]



Full circularity in the system is achieved when the consumption of resources reaches a plateau, which requires systemic change on multiple levels. Strategies for systemic change involve both (1) industries and (2) citizens. Introducing strategies targeting both actors connects production

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[2] The feedback loops included in the diagram are formed by the following variables:

- R1: disposable income > demand > production > employment.
- R2: resource consumption > resource cost > profit > material efficiency
- R3: profit > production > resource consumption > end of life materials > recovered materials > materials to landfill > taxation > resource cost
- B1: production > resource consumption > resource cost > profit
- B2: resource consumption > end of life materials > recovered materials
- B3: production > resource consumption > end of life materials > materials to landfill > taxation > profit
- B4: demand > production > resource consumption > GHG emissions > well being > behavioral change
- B5: demand > production > resource consumption > end of life materials > materials to landfill > well being > behavioral change

and resource management to demand in a synergetic way (rather than creating a tradeoff, as described earlier). These two major feedback loops are illustrated by the two bold orange arrows in Figure 2-4. First, demand for new products can be curbed with maintenance and repair, refurbishing, but also through rethinking, refusing and re-using products. Second, production and competitiveness are sustained by the employment creation that these circular economy strategies create, through repurposing and remanufacturing, among other examples.

A more detailed version of the CLD presented above is presented in Figure 2-5, and a brief description of this diagram follows.

First, the CLD includes several variables, such as “production” and “material efficiency”. The former is an indicator, while the latter is an intervention. The interventions are presented in different colors, to identify actions that can be taken by the government (green), private sector (brown) and citizens (pink).

Second, the CLD shows casual relations between variables and interventions. As an example, an increase in production leads to an increase in material consumption, all else equal (and hence a “+” sign is added to the arrow linking these two variables); on the other hand, an improvement in resource efficiency could reduce material consumption, possibly even in absolute (in addition to relative) terms.

Third, the CLD includes notations for feedback loops, reinforcing (R) and balancing (B). An example of reinforcing loop is represented at the centre of the diagram: production > employment > population (and disposable income) > demand > production. Feedback loops change in strength depending on local circumstances, and hence local customization is required. As a result, the CLD can show why certain policies may be more effective in a certain regional context than in others (e.g. in one case the feedback loop representing resource scarcity may be very relevant, while in other cases not at all).

The CLD indicates that the historical growth of disposable income has led to growing demand and production. There are two consequences of this trend (i) and increase in employment, which leads to the creation of disposable income and more demand (creating a reinforcing loop -R1-) and (ii) the increase of resource consumption. Higher resource use has led to three main outcomes (a) more waste generation, (b) higher emissions and (c) growing production costs. These three outcomes create balancing feedback loops (B1, B3) that contrast the initial reinforcing loop. In other words, the past economic growth has led to the emergence of side effects. Specifically, (a) more waste generation leads to higher accumulation into the landfill or incineration, leading to higher (b) emissions and human health impacts; (c) the growing use of resources leads to higher resource and production costs, which negatively affects profits and the potential expand production, hence limiting the growth triggered by the first reinforcing loop.

The introduction of circular economy interventions has several consequences on the behavior of the system. First, investments in recycling infrastructure can reduce the accumulation of waste in the landfill and incineration, reducing resource consumption and the cost of production, as well as emissions (B2). Further, recycling leads to employment creation as well as to (possibly) higher profits (R4 and R5), both of which, on the other hand, create income and lead to more demand and production and hence resource use. As a result, the effectiveness of recycling may be challenged by its positive economic impacts.

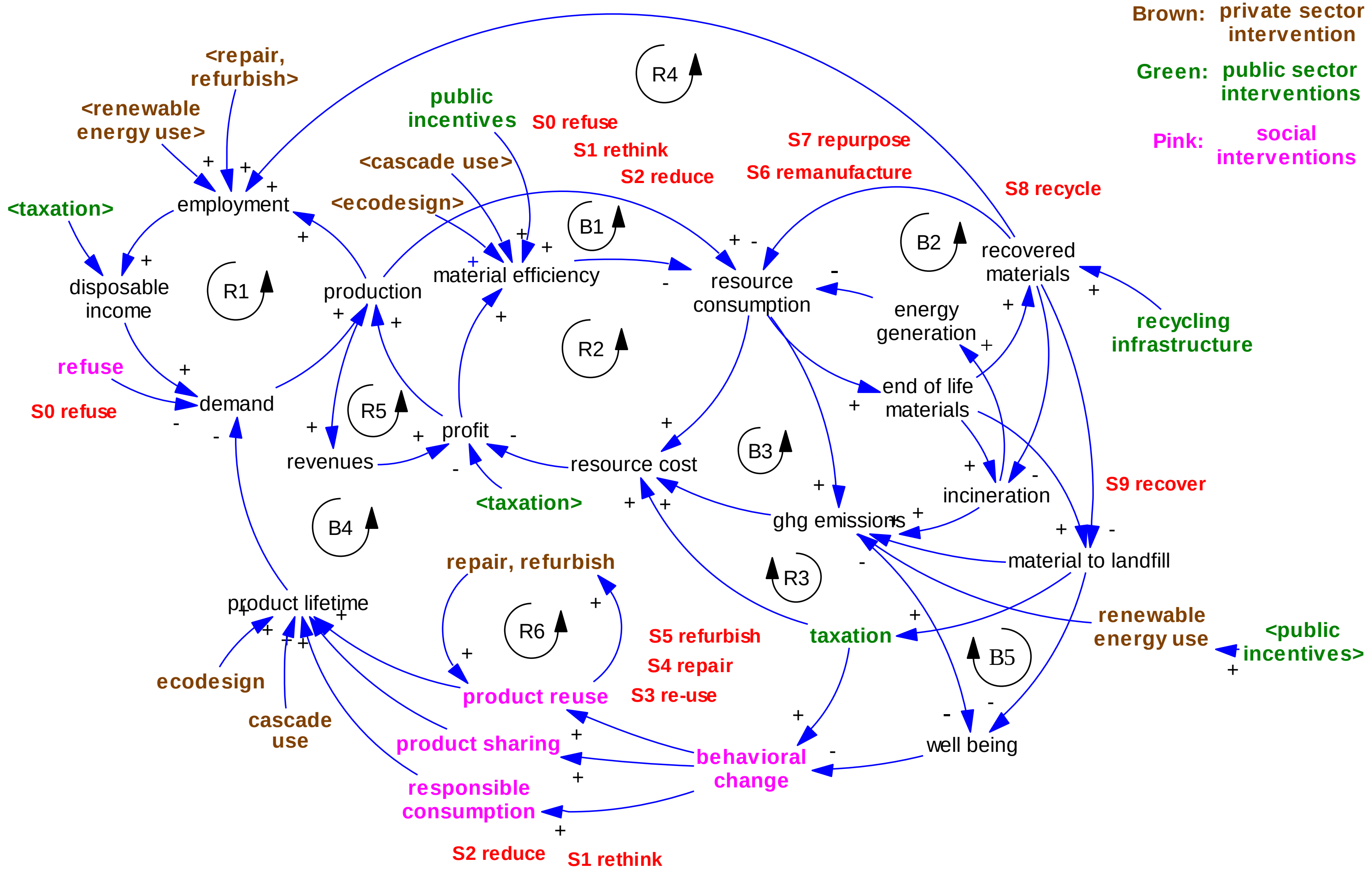
Specifically, we see two dynamics at play: (i) the reduction in material use and landfilling due to waste recycling and reuse, and (ii) the increase in material use due to the economic growth triggered or enabled by waste recycling and reuse. It results that the actual net reduction in materials use and ultimately waste landfilling is likely to be smaller than expected, or even higher, because of the balancing effect of item (ii) described above. This emerging dynamic is known as 'rebound effect', wich stems from the classic Jevon's Paradox (Polimeni JM and Polimeni RI, 2006). It is explored frequently in the energy sector in the context of energy efficiency investments (Grubb MJ, 1990), and results from the simultaneous presence of reinforcing and balancing loops in the system analyzed.

In order to mitigate the strength and impact of the rebound effects, recycling could be coupled with interventions that aim at improving material efficiency, such as public incentives as well as private investments in eco-design and cascade use (B1, R2 and R5). Similarly, emissions could be curbed through the introduction of incentives, and investments in renewable energy. In summary, as indicated earlier these interventions reduce costs and increase profits, creating space for expanding production and consumption.

A more effective synergy is found when demand-side interventions are implemented in conjunction with supply-side policies and investments. The higher effectiveness is depicted by the fact that a strong balancing loop is introduced (B4) with demand-side interventions. Specifically, if taxation, repair, refurbishment and remanufacturing are introduced behavioral change emerges for product reuse, product sharing and responsible consumption. These three factors lead to longer product lifetime, which can also be impacted by eco-design and cascade use, interventions implemented by the private sector. With a longer lifetime of products demand declines, the same effect that can be expected from the refusal of consumption, and hence production will not grow as fast, or even decline.

The simultaneous implementation of demand- and supply-side interventions will lead to a complete shift in the dynamics of the system. In fact, a circular economy is one that strives even if there is no growth in consumption and production, due to material efficiency and the recycling and reuse of materials, as well as products. In this scenario waste landfilling and emissions would decline, as would health impacts, leading to lower taxation and improved well-being.

Figure 2-5 : Detailed integrated CLD



Legend of the Detailed integrated CLD shown in Figure 2-5 :

- A **causal link** from variable A to variable B is positive if a change in A produces a change in B in the same direction; a causal link from variable A to variable B is negative if a change in A produces a change in B in the opposite direction. Example: the more demand, the more production (plus sign); the more production costs, the less profits (minus sign).
- **Feedback loops**, represented in the diagram with R or B sign surrounded by a circular arrow, can be classified as positive or negative. Positive (or reinforcing) feedback loops amplify change and are typically identified by a 'R' notation, while negative (or balancing) counter and reduce change are identified by a 'B' notation. Example: the more demand, the more production, the more employment, the more disposable income and the more demand (reinforcing loop); the more resource consumption, the more waste generation, the more recycling and the less resource consumption (balancing loop).

3 Territorial factors in the Causal Loop Diagram

In order to design effective policies, territorial specificities should be taken into account. These are presented next, emphasizing the impact that each territorial characteristic can have on the system (i.e. enabling the effective implementation of circular economy interventions).

3.1 Agglomeration

Agglomeration affects both strategies directed at industries as well as strategies aiming at changing citizen behaviour. As illustrated in Figure 3-7, agglomeration affects three key feedback loops, material recovery (B2), resource consumption and material efficiency (R2), and repair, refurbish and reuse (R6).

For industries, agglomeration can yield significant cost reductions. Agglomerations are regional concentrations of activities in groups of related industries that benefit different advantages (i.e. knowledge spill-overs, labour pooling, input sharing).

In the case of loop (B2), agglomeration increases the chance to reach the critical mass required for enabling certain circular economy practices to become profitable, such as for example recycling. The recovery of end-of-life materials only becomes profitable if a continuous stream of materials is available. Further, increasing agglomeration contributes to increased the intrinsic innovative capacity and potentially provides substitution synergies (i.e. remanufacturing) that can be implemented among firms.

Concerning material efficiency (R2), agglomeration can enable market penetration for circular economy service providers and technology developers. In other words, industrial agglomeration potentially accelerates circular economy practices such as eco-design, cleaner production or industrial symbiosis that reduce the material footprint of a business or an industry. The reduction in costs and the increased potential for production resulting from higher material availability has the potential to contribute to increasing the competitiveness of an industrial cluster or sector compared to comparable, less agglomerated areas.

As with material recovery (B2), the repair, refurbishment and reuse (R6) of goods and materials requires critical mass to become attractive for both businesses and consumers. The more agglomerated a region, or industrial cluster is, the higher the probability that products can be reused and that substitution synergies may emerge, and the more likely there is demand for repair and refurbishing businesses that respond directly to the local needs. Technology providers may deliver innovative solutions for sustainable development that respond to local scenarios, such as community driven energy programs, creative maker-networks like Fab Labs, repair and reuse networks (Prendeville et al., 2018), or sharing and circulating network like Coffee Clubs (Holmes, 2018).

Figure 3-6: Agglomeration in the simplified CLD

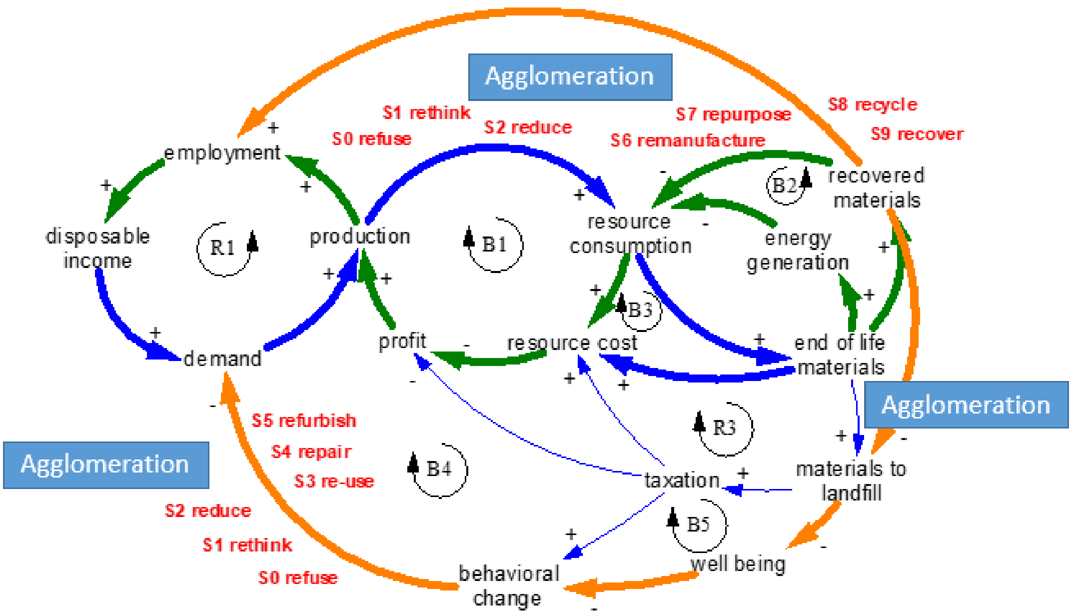
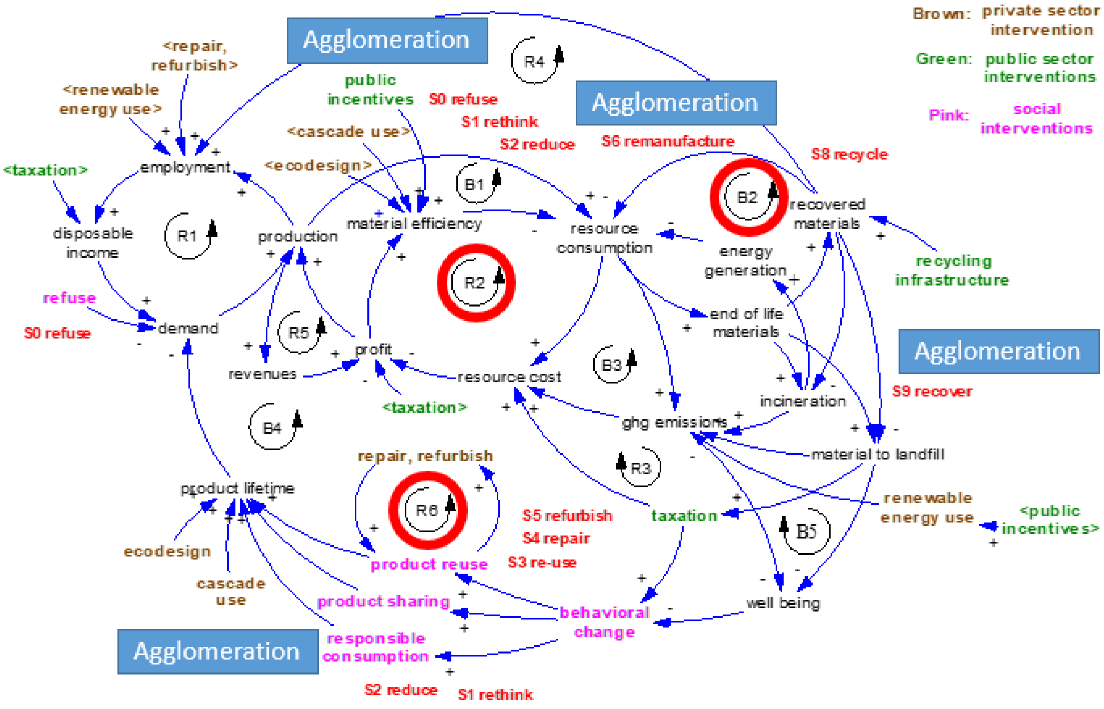


Figure 3-7: Feedback loops affected by Agglomeration



3.2 Land-based resources

The circular economy focuses on the efficient use of natural resources derived from our natural capital and is highly dependent on the functioning of biological cycles to produce e.g. food, other biomass and the provision of fresh mineral resources (Breure et al., 2018). In the context of the proposed CLD, land-based resources affect feedback loops related to material use (R2) and recovery (B2) as well as the potential for using renewable energy.

For the assessment of land-based resources, the dynamics of both feedback loops ought to be considered at the same time. Biomass is at the core of the biotic circular flows. Bio-based material demand is increasing worldwide and there is a growing need to assess and better understand how much biomass is available and can be mobilized sustainably. The main biomass sources are usually classified in three categories: agriculture, forestry and waste, whereby agriculture and forestry are the sectors most reliant on natural-based factors. These and other questions are addressed through assessing the interplay of material use (R2) and recycling (B2), as the amount of land and biomass recycled determine the demand for additional land conversion for biomass production. Loop (B2) focusses on the amount of land and/or biomass that can be recovered or recycled at a given point in time. Assuming that secondary materials are of comparable quality and lower price, the recovery of materials curbs the demand for virgin materials, while the recovery of land reduces land conversion for additional biomass production.

In addition to reducing environmental pressures, the conversion of land uses can also serve non-biomass related production services such as the generation of renewable energy. While biomass itself can be considered a resource for energy production, land requirements of renewable power generation technologies (i.e. solar PV and hydropower) are high and land is typically occupied for the lifetime of the assets (20+ years). To commit to such a long-term investment, recycling brownfields for renewable energy use or converting existing, fallow land require the right incentives for citizen and businesses to act.

Figure 3-8: Land-based resources in the simplified CLD

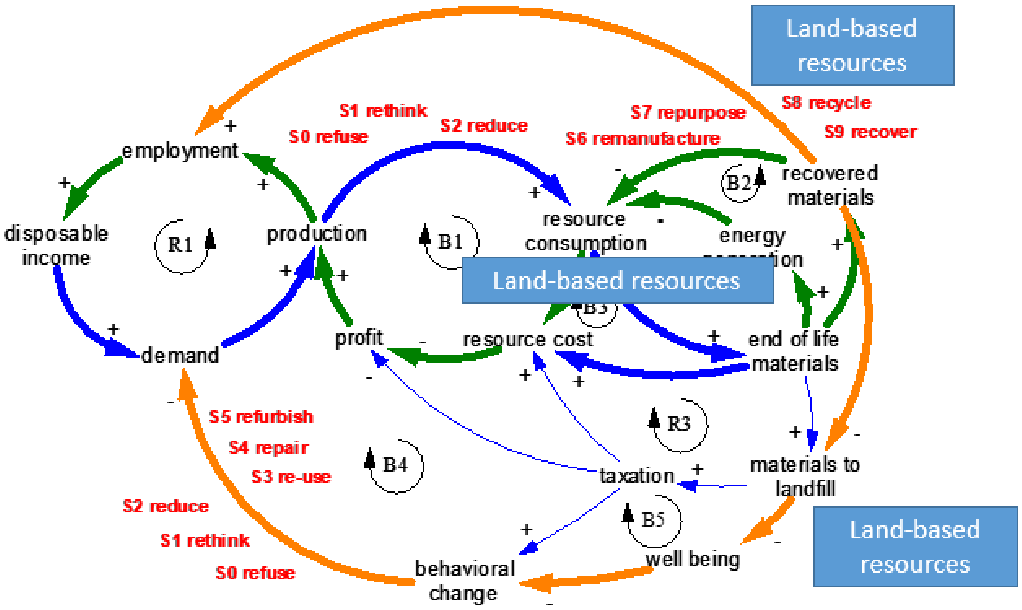
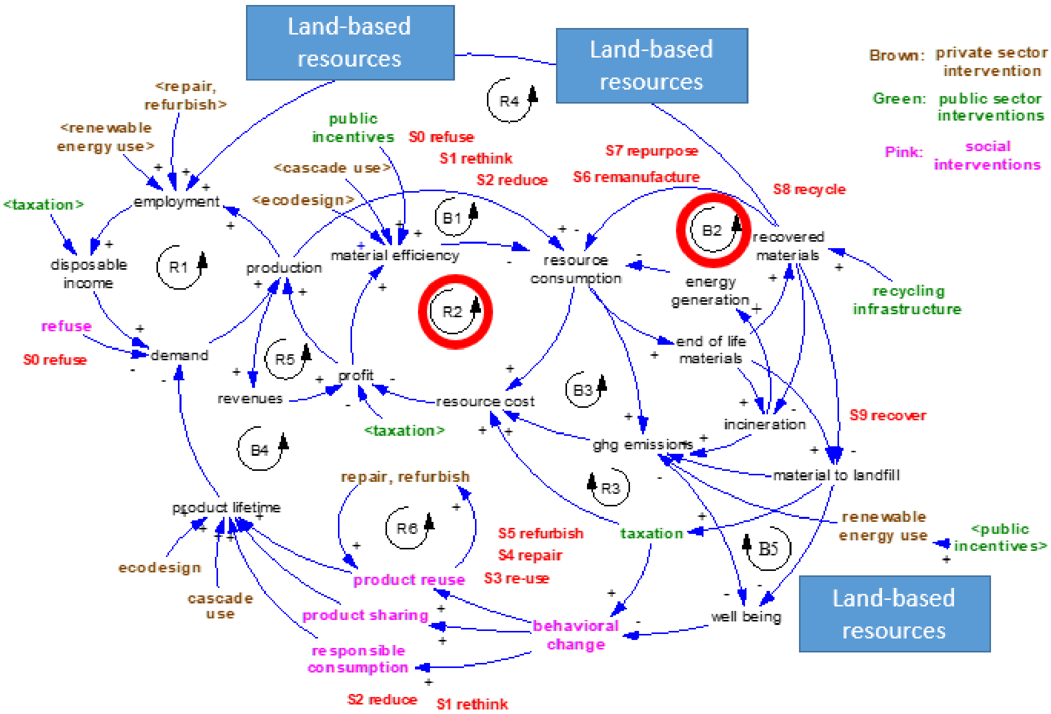


Figure 3-9: Feedback loops affected by Land-based resources



3.3 Accessibility

The actual existence and intensity of material flows occurring in closed loop networks will depend, among other factors, on the accessibility of individual economic actors, which in turn is conditioned by overall territorial accessibility (Accorsi et al., 2015). As illustrated in Figure 3-11, accessibility affects the resource consumption (R2) and recovery (B2) loops, and citizen-driven circular actions related to the reuse, sharing and consumption of goods (B4).

From a resource consumption and material efficiency perspective (R2), accessibility refers to key aspects such as access to the resource itself, and on a more aggregate level, among others, access to knowledge, technology, finance, skills, labor, infrastructure. Access to these and other factors can be harnessed to drive innovative circular economy actions within an industrial cluster or sector that contributes to reducing its material footprint.

Especially access to adequate infrastructure represents a determinant enabling factor for transitioning towards a circular economy, particularly considering the financial resources to build them. While resource efficiency is often thought to be the responsibility of businesses themselves, public actors are often regarded to be responsible for providing disposal and recovery infrastructure. The recovery of materials (B2) requires both end-of-life materials and recovery facilities to be accessible for a sufficient amount of actors. If access to either resources or facilities is not provided, the chances for a recovery industry to emerge are likely very low. In other words, if there is not a good relational network in place that ensures information exchange for an optimal resource management, it is likely that the potentials for circular business models will remain unfulfilled, and the existing 'hard' infrastructures will remain under-utilised.

Figure 3-10: Accessibility in the simplified CLD

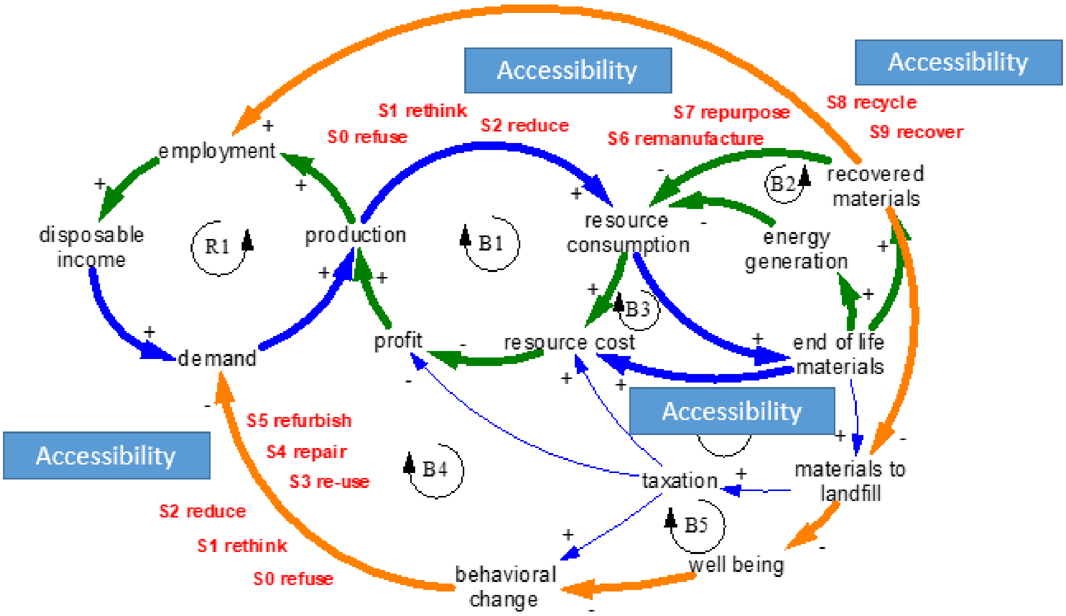
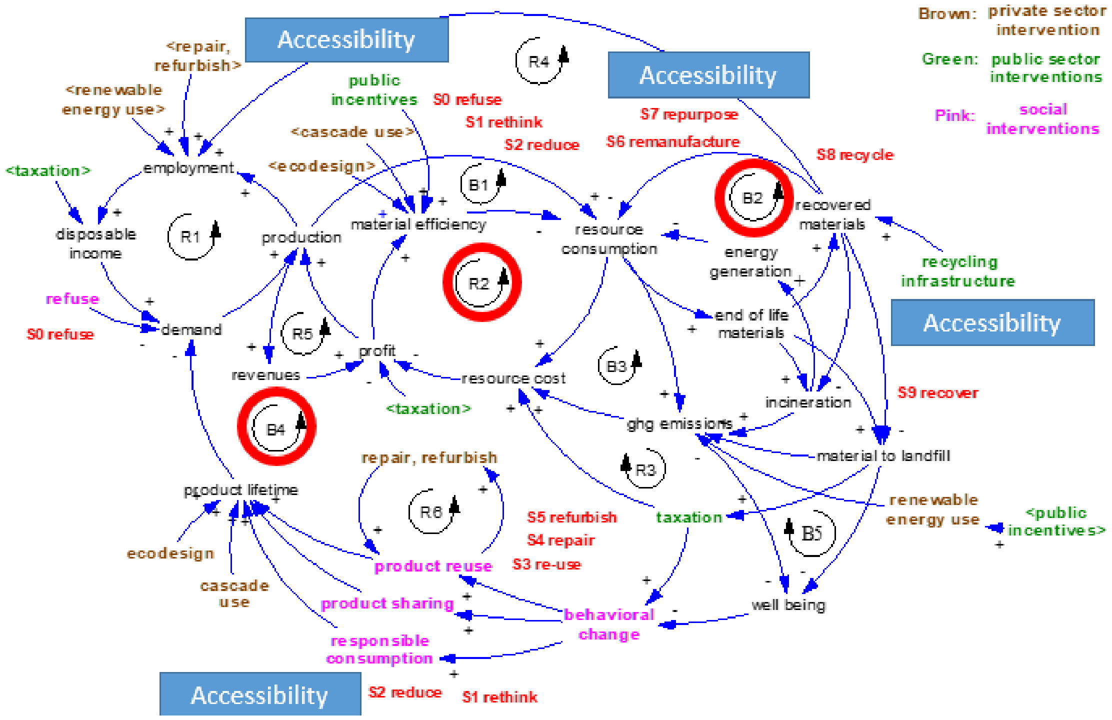


Figure 3-11: Feedback loops affected by Accessibility



3.4 Knowledge

Given the relative novelty of the circular economy concept, the installed knowledge-base at territorial levels becomes a fundamental ingredient of successful transitions. As illustrated in Figure 3-13, knowledge as a territorial factor impacts five key feedback loops of the system. It affects material consumption (R2) and recovery (B2), waste management policies (R3), and behavioral change for both citizen (B4) and businesses (R4).

Different types of knowledge are required for the development of a circular economy. Changes in resource consumption (R2) and recovery (R4) depend on the design and implementation of new and improved product design and production processes, such as for example resulting in eco-design, life-cycle thinking or the adoption of new business models. Concerning the consumption of resources (R2), process knowledge contributes to streamlining production processes and developing skills required to reducing the required material input per unit of output. In other words, knowledge has the potential to contribute to increasing material efficiency, which leads to reduced costs and increased availability of resources compared to the current paradigm. Further, the recovery of end-of-life materials (B4) from various sources requires knowledge of the different material flows and the processes required to separate those materials that ought to be reused, and how these can be reused. The implementation of this knowledge could significantly increase the stream of recovered materials and contribute to reducing both the amount of virgin materials and the land required for landfilling.

In addition to the proper governance of material consumption and recovery processes, territorial knowledge about circular economy processes and actions is crucial for effective policymaking (R3). For instance, it is well known that effective regulations are strongly influenced by the specialised knowledge owned by the actors within territories, and by the intensity of the cooperation they can put in place (Marra et al., 2018). This implies that awareness of the current territorial development stage as well as policy instruments for effectively guiding the local context towards circular economy are required for effective policymaking.

Knowledge is a crucial asset for the behavioural change of citizen (B4) and businesses (R4). For citizen, awareness of and access to alternative product that are more sustainable, or have a longer lifetime is important to allow them to take informed decisions regarding their lifestyle and consumption. For businesses, knowledge refers to business intelligence and the availability of the right skills in the workforce. The transition towards a circular economy calls for technical skills which are currently not present in the workforce (EC, 2014). Skills would for instance enable businesses to design products with circularity in mind, and to engage in reuse, refurbishment and recycling. The development of these skills, in collaboration with local think tanks or through the university systems (master and doctorate degrees), serves as an enabler for circular action and the implementation of circular economy processes.

Figure 3-12: Knowledge in the simplified CLD

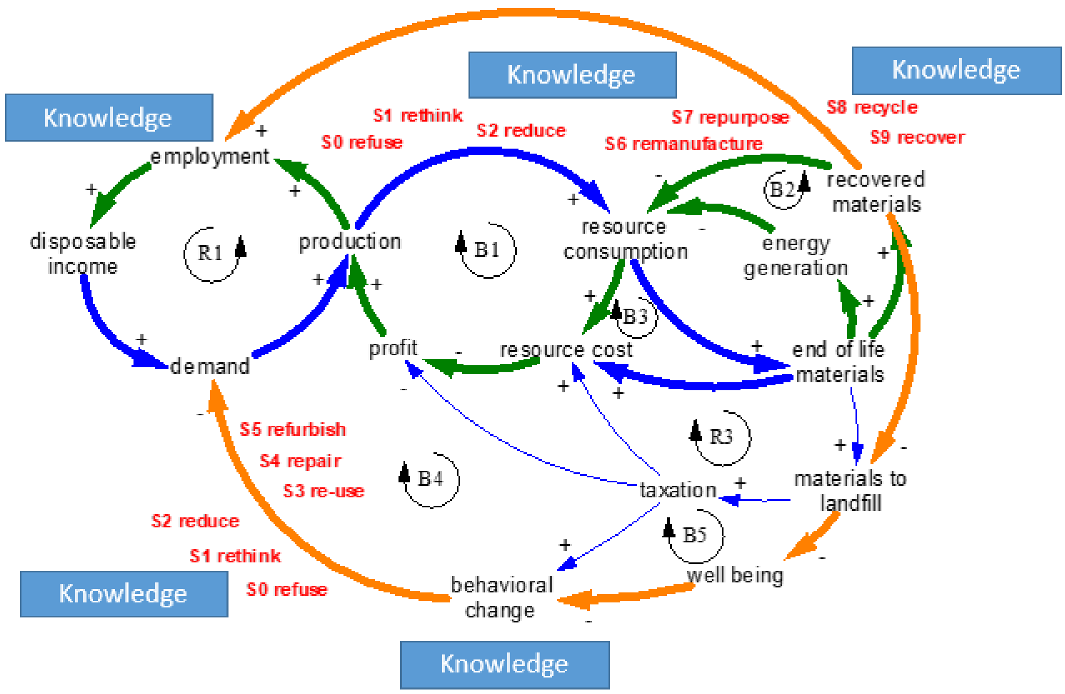
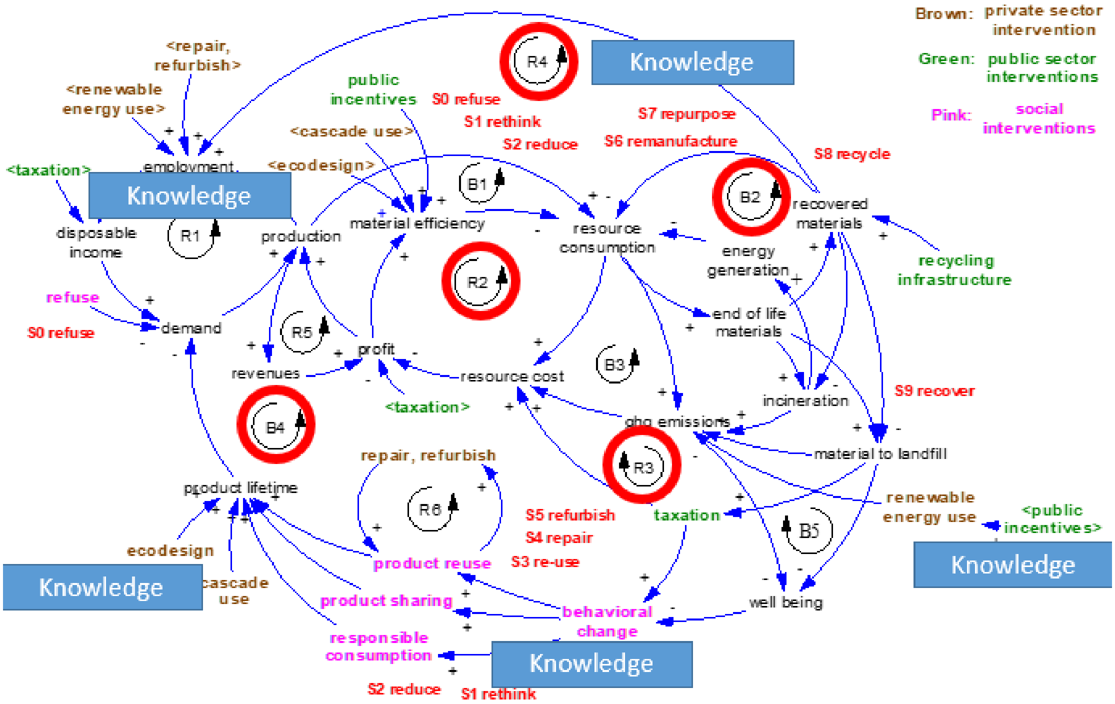


Figure 3-13: Feedback loops affected by Knowledge



3.5 Technology

All technologies can have a significant impacts on the success of transitioning towards a circular economy, both existing and upcoming ones. Circular economy innovations, designed for product reuse, remanufacture and refurbishment, have to compete in the market with more conventional recycling technologies and waste management systems, mostly structured around low-quality recycling and rudimentary energy-recovery solutions. When it comes to investing in technology, the bottom-line is that the strategic investment decisions taken at any point in time may have an impact well beyond the expected pay-back and amortization periods of those investments. As illustrated in Figure 3-15, technology can have significant impacts on the demand for products and employment creation (R1), material efficiency and consumption (R2), material recovery and resource consumption (B2), and behavioural change (B4).

Technological developments can unlock material streams for recovery and reuse, improve efficiency in the production process, allow to develop more durable and circular products. When coupled with cost reductions and increased utility, technology leads to higher disposable income as well as growing demand and production of goods and services, forming a reinforcing loop (R1). On the other hand, current technological trends such as increasing automation of manufacturing and waste separation facilities have led to reductions in employment as well.

In addition, technological innovation holds the potential to improve material efficiency, which reduces total resource costs, or opens up additional resources for production by using less per unit of output (R2). As indicated above, technological developments can contribute to unlocking resource streams for recovery, increasing the share of end-of-life materials that can be recovered and contributing to the development of the critical mass required for the establishment of specific circular practices (B2).

In addition to business related impacts, technology could play an important role in facilitating behavioural change. Many apps aiming at the dissemination of leftover food from restaurants, sharing goods and services, or renting transportation have been developed that increase the convenience for consumers to access and participate in circular markets. New technologies and business models have the potential to fundamentally change the way in which we consume goods and services, or the way that we treat waste.

Figure 3-14: Technology in the simplified CLD

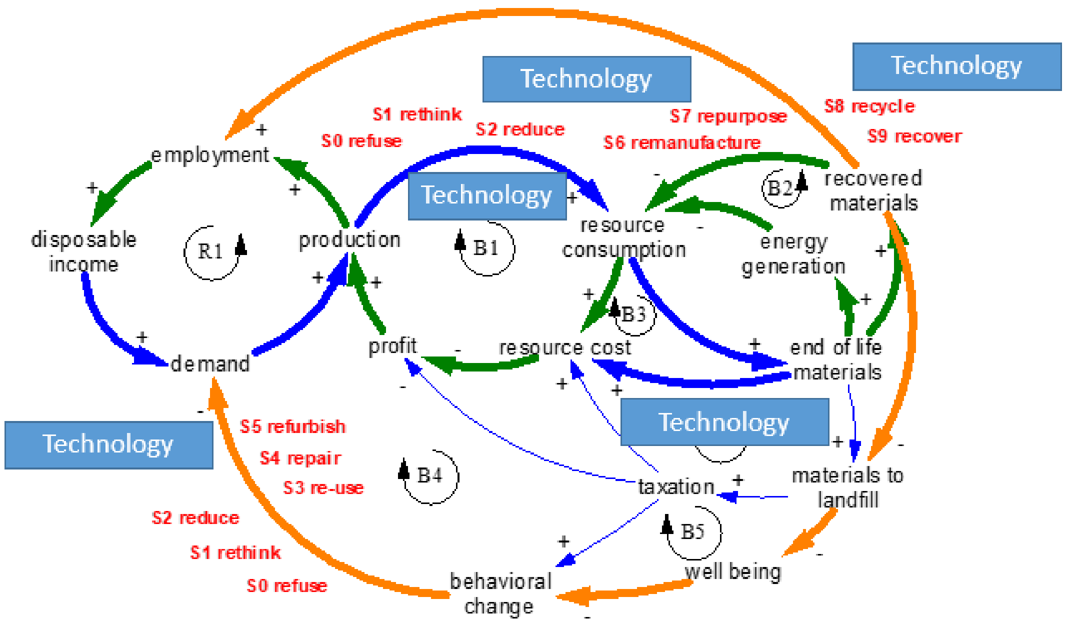
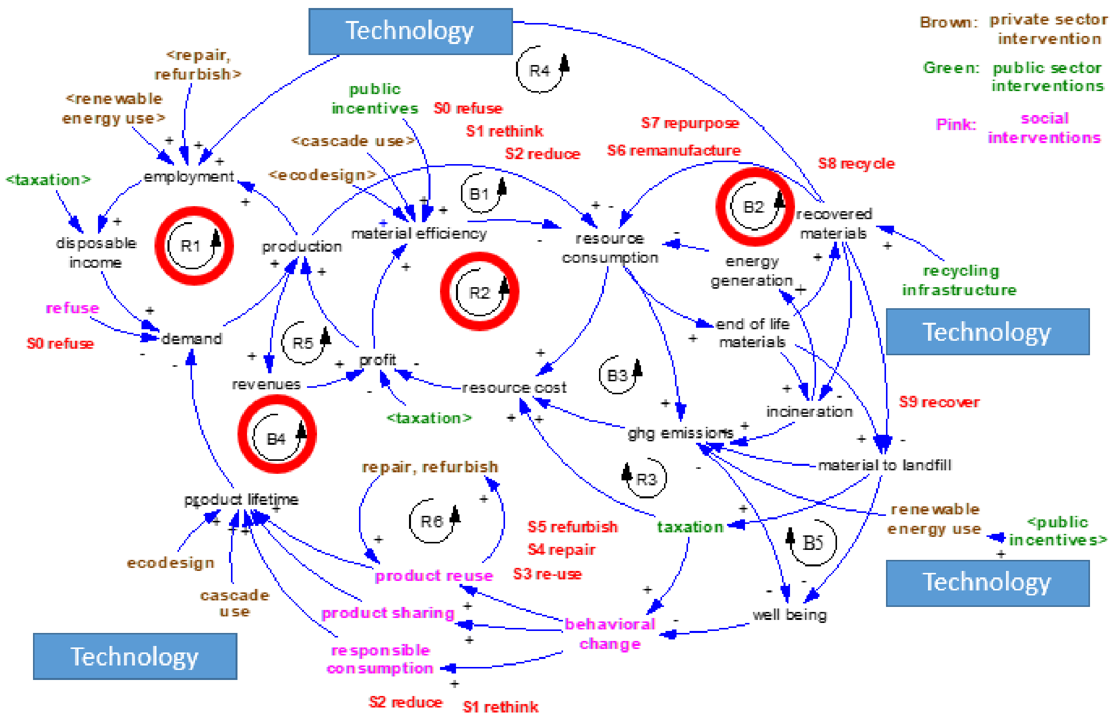


Figure 3-15: Feedback loops affected by Technology



3.6 Governance

Governance and institutional systems are key enablers for the transition to a circular economy. While EU and national policies and targets create the overall framework of operation, regions and municipalities play a key-role in translating this vision into regional and local realities. Governance affects the regulatory environment and has the potential to influence industrial sectors or whole regions in favor of (or against) circular practices, e.g. by disincentivizing unsustainable practices, or stimulating sustainable ones (R2) or by contributing to generating vast amounts of end-of-life materials through sorting and recycling infrastructure (B2). Regulations and policy frameworks could contribute to providing a clear sense of direction concerning economic policy in the coming years, which potentially provides enough security for businesses to make investments with longer payback times. The key feedback loops that are affected by governance as a territorial factor are presented in Figure 3-17: R2 and B2, as described above, and R3.

Governance also plays a key role concerning the management of undesirable side effects of material management and the implementation and enforcement of regulation (R3, B3). Taxation is a policy measure extensively used to manage waste, and “polluter pay” fees have been used both for air and water pollution where a point source approach was required.

Figure 3-16: Governance in the simplified CLD

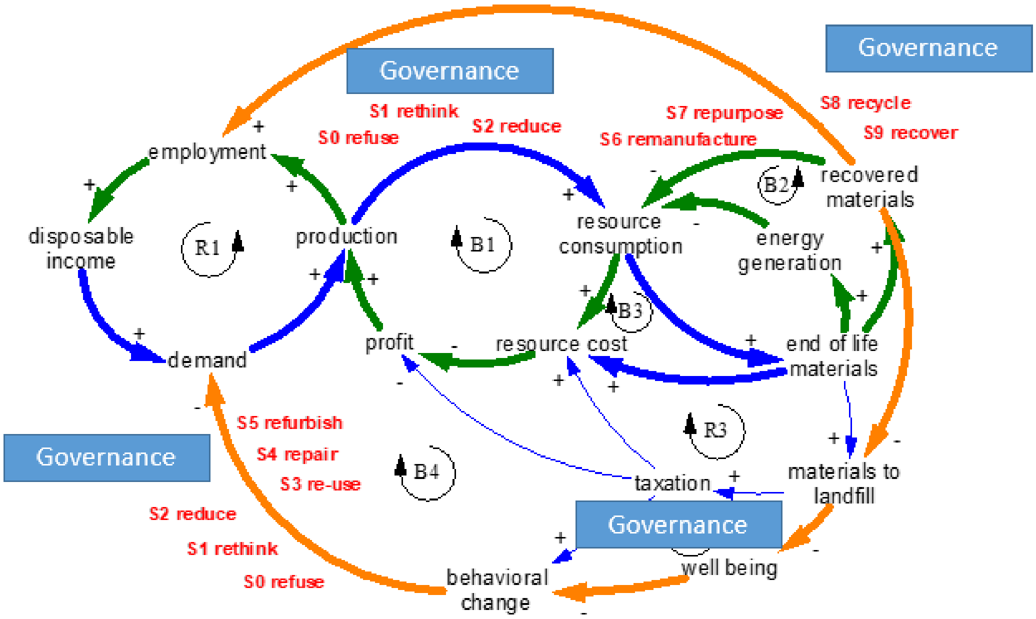
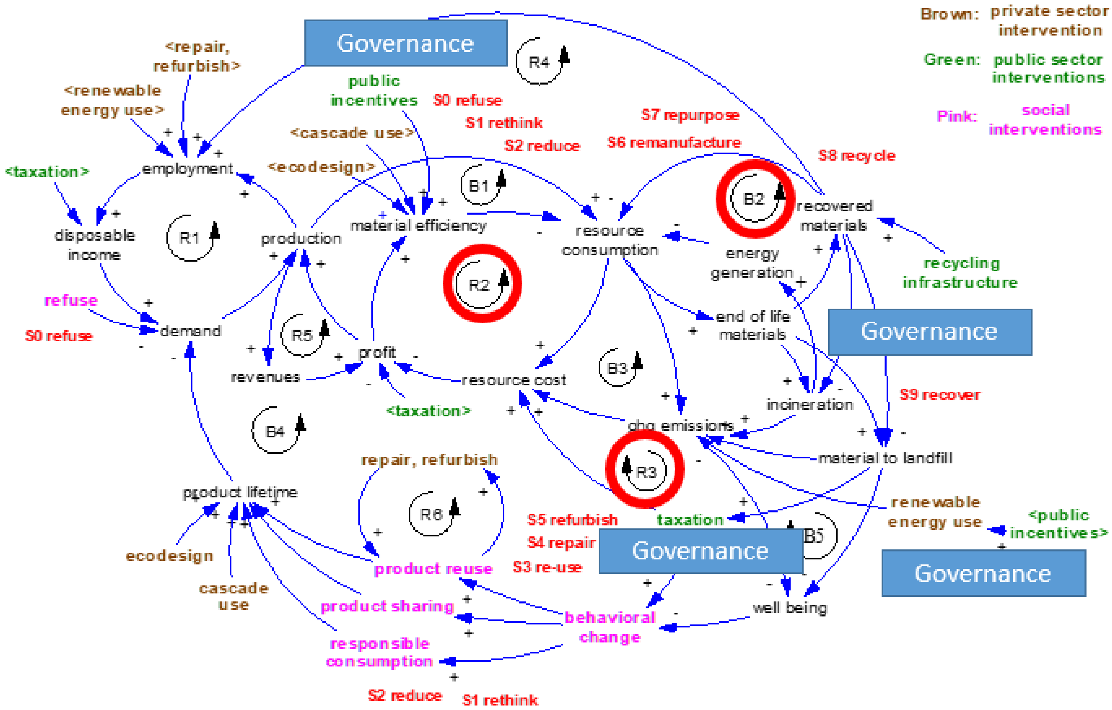


Figure 3-17: Feedback loops affected by Governance



3.7 Territorial milieu

In close connection to governance and institutional factors, it has been claimed that a strategic and shared vision of a region is a major driver for achieving ambitious techno-economic transitions, such as the circular economy (Preston 2012). A strong sense of belonging and territorial loyalty coupled with a far-sighted business perspective, are prerequisites to such a vision. Territories where such factors are embedded in the local culture and business models tend to have a high degree of innovative capacity, and are more dedicated to collaboratively realize disruptive changes. As illustrated in Figure 3-18, the territorial milieu potentially impacts feedback loops related to material efficiency (R2) and recovery (B2), as well as the regulatory environment (R3).

Process improvement is an area where the presence of a strong territorial milieu can play an important role. There are several industrial districts and clusters worldwide, where success was created thanks to the shared knowledge that was made available by visionary local business leaders. In these context new knowledge and skills were created through the sharing of information, rather than protecting it. As a result, the reinforcing loop R2 can certainly be enabled by the territorial milieu, where leaders in the manufacturing sector can stimulate action by others, including government. The same may happen for citizens, through the reinforcing loop R6, where trust between consumers and local producer can lead to a strong partnership resulting in the reuse of products, their repair and refurbishing. Finally, such strong partnership can be strengthened by the government, with actions aimed at supporting well being (e.g. reducing waste landfilled and stimulating responsible consumption), as represented by the balancing loop (B4). The mention of several stakeholders is not fortuitous, in fact the milieu itself favours the participation of a wide group of regional stakeholders - public, private, non-governmental sector and academia - resulting in favourable collective action, easier people-to-people agreements and simpler identification of local synergies.

Figure 3-18: Territorial milieu in the simplified CLD

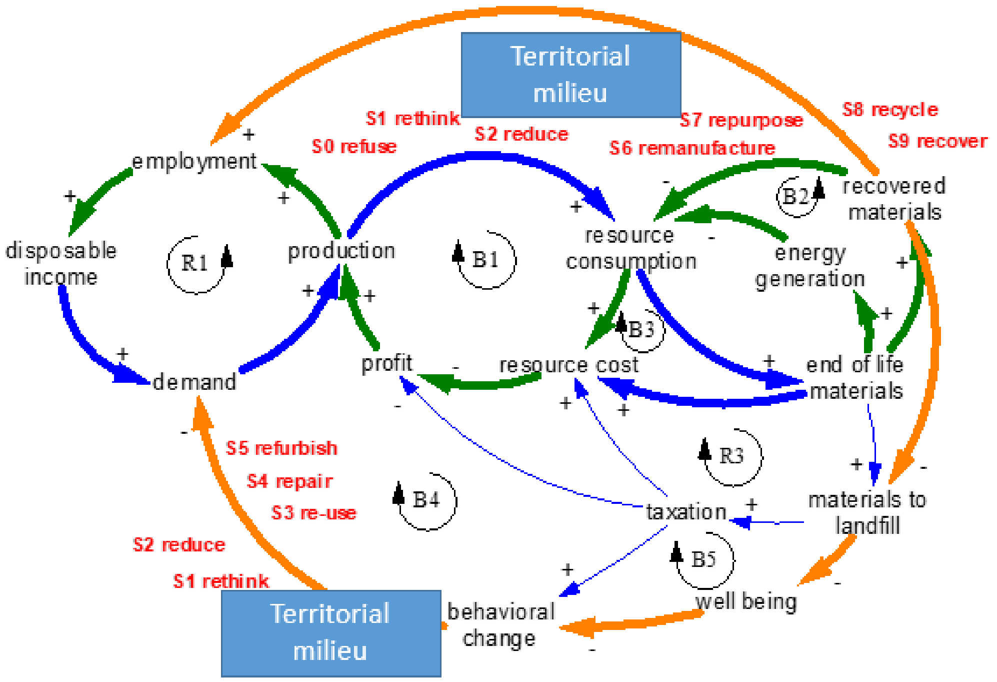
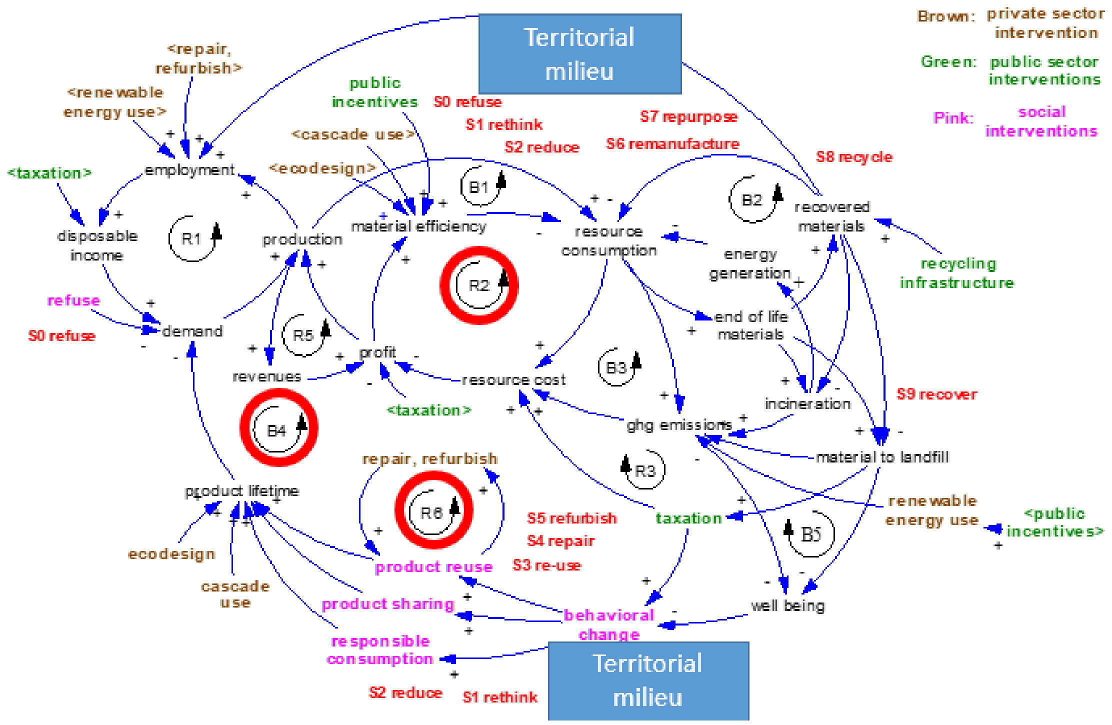


Figure 3-19: Feedback loops affected by Territorial milieu



4 CLD documentation

This section presents the documentation of the general CLD. Figure 4-20 shows the diagram with both variables and arrows numbered. Two tables follow, one listing the variables and providing information on their definition; and one listing causal relations and providing information on the type of causality and the rationale for having such causal relations between variables.

Figure 4-20: Numbered CLD (variables and causal relations)

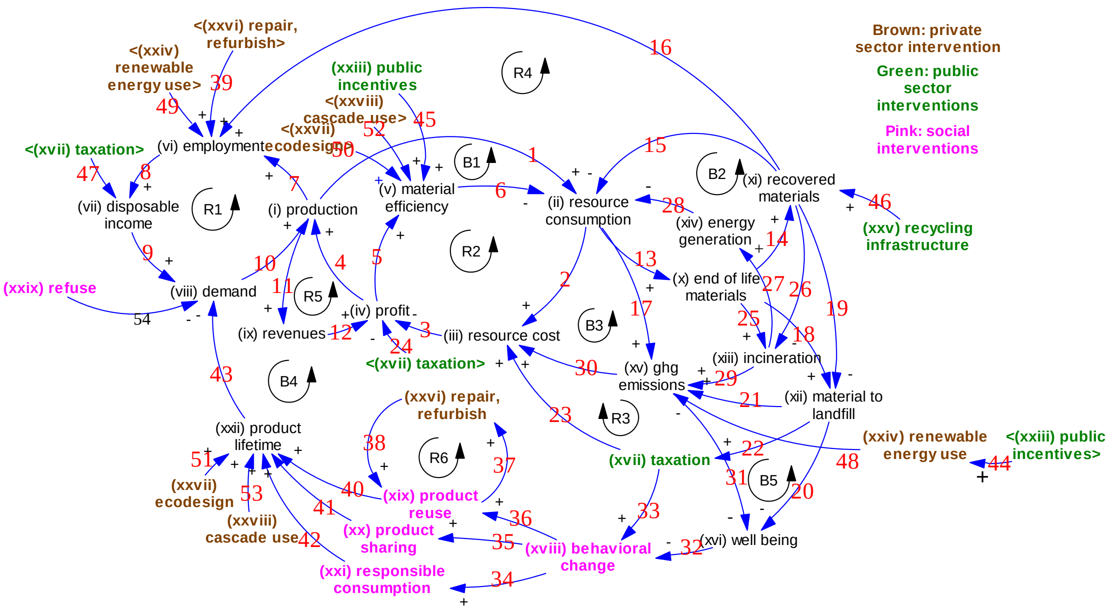


Table 4-1: List of variables used on the causal loop diagrams

#	Variable	Documentation
(I)	Production	Defined as physical production in industrial sectors, requiring the use of inputs and leading to production outputs and end of life materials.
(II)	Resource Consumption	Resource consumption represents the use of labor, materials, water, and/or energy for the production of goods and services. “'Materials' sometimes refers to primary or raw materials, understood as virgin materials extracted from the natural environment. This normally includes biomass, metal ores, non-metallic minerals and fossil energy carriers.” (EEA, 2016b, S. 22) Concerning water use, it can be stated that “industry uses water to create steam, generate electricity, cool and heat processes, clean components, or produce products.” (McDonald, 2005, S.

		317). In terms of energy consumed during the production process, this study consider direct and feedstock energy use, disaggregated by energy source and energy service.
(III)	Resource cost	Resource cost covers total cost of production. “Goods and services are produced using combinations of labor, materials, and machinery, or what we call inputs or factors of production.” (OpenStax, 2014, S. 56). The sum of the costs for all inputs to the production process are the production costs. Estimated as the cost of production (quantity consumed multiplied by price), specifically the cost of resource inputs (e.g. materials, energy, water). “Labour cost per unit of output (in short, unit labour cost) is defined as nominal labour compensation divided by real value added. Total labour compensation includes wage compensation and other labour costs such as employers’ contributions to social security and pension schemes and labour cost of the selfemployed.” (Ark & Minnikhof, 2000)
(IV)	Profit	Profits are the difference between revenues and costs of production (OpenStax, 2014, S. 56).
(V)	Material efficiency	Material efficiency, or 'resource efficiency', “denotes the political goal of 'allowing the economy to create more with less, delivering greater value with less input, using resources in a sustainable way and minimising their impacts on the environment'.” (EEA, 2016a, S. 22)
(VI)	Employment	The total amount of full time equivalent (FTE) jobs created in the economy.
(VII)	Disposable income	Disposable income is defined as “income after taxes”, indicating the take-home pay of consumers (OpenStax, 2014, S. 304)
(VIII)	Demand	“[T]he amount of some good or service consumers are willing and able to purchase at each price.” (OpenStax, 2014, S. 47). This factor also considers the demand for export, which can be regarded as “the goods and services that are produced domestically and sold abroad.” (OpenStax, 2014, S. 20)
(IX)	Revenues	Total revenue is estimated as price multiplied by the quantity of goods sold (OpenStax, 2014, S. 115).
(X)	End-of-life materials	Materials that cannot be put to good use after the production process, and are therefore discarded. According to the European

		Parliamentary Research Service (2017), approximately 2.6 billion tons of end-of-life materials were generated in the EU-28 in 2014, which was the highest amount of waste ever recorded. “Construction contributed the highest share in 2014 (33.5 per cent) followed by mining and quarrying (29.8 per cent), manufacturing (9.8 per cent), households (8.1 per cent) and energy (3.7 per cent); the remaining 15 per cent was waste generated from other economic activities, mainly including waste and water services (8.8 per cent) and services (3.8 per cent).” (EPRS, 2017, S. 31)
(XI)	Recovered materials	Recovered materials refers to the practice of diverting or extracting valuable raw materials from waste streams (OECD, 2013; EPRS, 2017). The reuse of materials from the waste stream is required to move from a linear towards a circular consumption model and can yield significant benefits. The recovery of critical raw materials, which are low quantity high value-added waste streams, would reduce the import dependency concerning these CRM. Revenues from e-waste recycling in Europe are currently estimated at EUR 2 billion and projected to increase as e-waste (growing at 3%-5% per year) is the fastest growing waste stream within the EU (EPRS, 2017).
(XII)	Materials to landfill	“[W]aste disposal sites for the deposit of waste onto or into land” (EC, 2016c). The costs of landfilling materials are often paid for through a landfill tax, which is “a levy charged by a public authority for the disposal of waste” (BIS , 2012)
(XIII)	Incineration	The IPCC defines (waste) incineration as “the combustion of solid and liquid waste in controlled incineration facilities.” (IPCC, 2006)
(XIV)	Energy generation	Energy generation refers to the production of electricity from both renewable and fossil fuel based technologies. It includes on-site, meaning off-grid electricity generation, and the recovery of energy from waste streams through the incineration of waste, also referred to as “Waste-to-Energy (WtE)”, whereby the latter one is particularly relevant for realizing a circular economy. “WtE technologies are able to convert the energy content of different types of waste into various forms of valuable energy.” (WEC, 2013). Energy types obtained from WtE can be power, heat or various biofuels.

		"The global WtE market was valued at US$25.32 billion in 2013, a growth of 5.5% on the previous year. WtE technologies based on thermal energy conversion lead the market, and accounted for 88.2% of total market revenue in 2013. 3. The global market is expected to maintain its steady growth to 2023, when it is estimated it would be worth US$40 billion, growing at a CAGR of over 5.5% from 2016 to 2023." (WEC, 2017)
(XV)	GHG emissions	The amount of air emissions generated from energy, waste and land use.
(XVI)	Well-being	The condition of an individual or group. It normally considers social (e.g. health), economic (e.g. income) and environmental (e.g. access to parks and nature) dimensions.
(XVII)	Taxation	Charges applied by the government to cover budgetary costs, including waste taxation. "Waste water taxes apply to direct dischargers, i.e. those entities which discharge directly into a recipient water, and possibly to the residual discharge from sewage treatment plants after treatment."
(XVIII)	Behavioural change	Behavior change refers to changing consumption and production patterns within a region, sector or economy.
(XIX)	Product reuse	"Re-use by another consumer of discarded product which is still in good condition and fulfils its original function." (Potting, Hekkert, Worrell, & Hanemaaijer, Circular economy: Measuring innovation in the product chain, 2017)
(XX)	Product sharing	Collaborative consumption, or the shared use of products by consumers, either peer to peer or mediated through a company, is a niche development that is increasingly becoming an important aspect of consumer behaviour. A survey conducted by consumer associations in four EU Member States (Belgium, Italy, Portugal and Spain) revealed that participation in these kinds of activities is quite high, reaching 72 % of those interviewed (OCU et al. , 2016)
(XXI)	Responsible consumption	"SDG 12 envisions sustainable consumption and production, which use resources efficiently, reduces global food and other waste, disposes safely toxic waste and pollutants. It also highlights the importance of strengthening scientific and technological capacity in developing countries to move to sustainable patterns of consumption and production and developing tools to

		monitor sustainable development impacts for sustainable tourism. ”3
(XXII)	Product lifetime	A product's lifespan is usually defined as the period from product acquisition to its disposal by the final owner (Murakami, Oguchi, Tasaki, Daigo, & Hashimoto, 2010). It is also referred to as a product's domestic lifespan. The period includes any repair, refurbishment or remanufacturing and periods of storage when the product is no longer in use — also called dead storage or hibernation (Bakker, Wang, Huisman, & den Hollander, 2014).
(XXIII)	Public incentives	Support provided by the government to share the cost of investments, or reduce the cost of compliance with a given policy.
(XXIV)	Renewable energy use	The amount of renewable energy used in the local energy mix.
(XXV)	Recycling infrastructure	The infrastructure available to support material recycling.
(XXVI)	Repair, refurbish, reuse	**Repair**: “Repair and maintenance of defective products so it can be used with its original function.” **Refurbish**: “Restore an old product and bring it up to date.” **Reuse**: “Re-use by another consumer of discarded product which is still in good condition and fulfils its original function.” (Potting, Hekkert, Worrell, & Hanemaaijer, Circular economy: Measuring innovation in the product chain, 2017)
(XXVII)	Eco-design	“[T]he integration of environmental aspects into product design and development, with the aim of reducing adverse environmental impacts throughout a product's life cycle.” (British Standards Institute, 2011)
(XXVIII)	Cascade use	“Cascading use of biomass resources, such as wood and agricultural products, means an efficient use of these resources from the point of view of natural resource, material and land consumption. It is effectively a principle to increase the productivity and efficient use of scarce and valuable raw material resources.

[3] Source: United Nations, http://www.un.org/sustainabledevelopment/sustainable-development-goals/ ; United Nations Development Programme, http://www.undp.org/content/undp/en/home/sustainabledevelopment-goals.html ; UN Factsheets ‘Why it matters’ and World Bank Group, (2017), Atlas of Sustainable Development Goals 2017 from World Development Indicators.

		The cascading use principle gives priority to higher value uses that allow the reuse and recycling of products and raw materials and promotes energy use only when other options are starting to run out. It concretely prioritizes material use of biomass before energy use since burning implies the raw material being lost. It also prioritizes energy production combined with 'co-products' such as compost or nutrients over energy productions only." (BirdLife Europe & EEB, 2016)
(XXIX)	Refuse	"Make product redundant by abandoning its function or by offering the same function with a radically different product." (Potting, Hekkert, Worrell, & Hanemaaijer, Circular economy: Measuring innovation in the product chain, 2017)

Table 4-2: List of causal links shown in the causal loop diagrams

#	Causal Links	Documentation
1	Production Influences Resource Consumption	The EU circular economy action plan outlines the importance of primary raw materials, including renewable materials in the production process (EC, 2015).
2	Resource Consumption Influences Resource Costs	The Ellen MacArthur Foundation estimates potential savings in material costs from implementing circular economy measures in the manufacturing of complex durable goods at USD 340-630 billion per year in the EU alone. The indicated savings are equivalent to approximately 12%-23% of current material input costs (EMF, 2012). According to Greenovate!, European manufacturing firms spend on average 40% of their cost on raw material, which increases to 50% of total costs if water and energy are included (Greenovate! Europe, 2012).
3	Resource Cost Influence Profits	"If a firm faces lower costs of production, while the prices for the good or service the firm produces remain unchanged, a firm's profits go up." (OpenStax, 2014, S. 56)
4	Profits Influence Production	"When a firm's profits increase, it is more motivated to produce output, since the more it produces the more profit it will earn." (OpenStax, 2014, S. 56) "[T]the willingness to supply, called the supply function, depends on the price at which the good can be sold as well as the cost of production for an additional unit of the good. The greater the difference between those two values, the greater is the willingness of producers to supply the good." (Eastin & Arbogast, 2011, S. 9)
5	Profits Influence Material Efficiency	"Sustainability programs are not only strongly correlated with good financial performance but also play a role in creating it." (Bonini & Swartz, 2014, S. 6)
6	Material Efficiency Influences Resource Consumption	Potential net benefits of implementing resource efficiency measures such as waste prevention, material recovery and re-design measures in the EU-27 are estimated at USD 245 – 604 billion, which is equivalent to 3%-8% of annual turnover (AMEC Environment & Infrastructure and Bio Intelligence Service, 2014). Capacity building and technological upgrades can yield up to 50% in cost

		savings in manufacturing businesses (Greenovate! Europe, 2012).
7	Production Influences Employment	Labor is considered as one of the inputs to the production process for goods and services (OpenStax, 2014). Everything else equal, an increase in production would yield an increase in employment. However, due to technological developments and the need for higher efficiency, most European manufacturing sectors have seen a decrease in the total number of jobs have
8	Employment Influences Disposable Income	According to OpenStax (2014), disposable income is the labor income that a person has at his/her disposure after deducting of taxes. The more people are employed (in the economy) the higher the total disposable income of families and communities, and hence their spending power.
9	Disposable Income Influences Demand For Products & Services	According to macroeconomic theory, the amount of money that people have available to spend on goods and services is correlated with the aggregate demand. An increase in disposable income leads to an increase in aggregate demand, while a decrease in disposable income leads to a contraction of aggregate demand (OpenStax, 2014, S. 291-294).
10	Demand For Products & Services Influences Production	As long as there is demand for a good and the good can be sold at a profitable margin, the prices
11	Production Influences Revenues	The revenues of a company depend o the number of items sold and their selling price. Assuming that there is demand for the good, an increase on items sold will hence increase the total revenues earned (OpenStax, 2014; IISS, 2016).
12	Revenues Influence Profits	Profits are estimated by deducting total costs from total revenues (IISS, 2016). A profit is generated once total revenues exceed fixed and the variable costs (break-even point). This implies that sufficient revenues beyond

		the break-even point need to be generated to generate a profit (IISS, 2016).
13	Resource Consumption Influences End Of Life Materials	"The amount of solid waste generated by economic activity is rising in line with growing consumption of material resources. Many valuable materials are disposed of as waste and, if not recovered, are lost to the economy. It is estimated that about one fifth of the raw materials extracted worldwide ends up as waste. This corresponds to over 12 billion tonnes (Gt) of waste per year" (OECD, 2013, S. 10)
14	End Of Life Materials Influence Recovered Materials	European countries are increasingly shifting towards a waste prevention and recycling type of management in order to move up the 'waste hierarchy', increase material recovery and hence reduce material dependency (EEA, 2016a; EEA, 2016b; EEA, 2017b). "The waste hierarchy prioritises waste prevention, followed by preparing for re-use, recycling, other recovery and finally disposal as the least desirable option." (EEA, 2017b). The above indicates that the amount of waste generated determines the waste that can be reused.
15	Recovered Materials Influences Material Consumption	"Valuable materials can also be gained from the recovery and recycling of solid waste by diverting materials from the waste stream before final disposal. They can further be extracted from final waste disposal sites such as landfills." (OECD, 2013, S. 10) The EEA estimates that the share of recycled materials consumed range from 2% in plastics to up to 42% for iron and steel (EEA, 2011). "An estimated 6–12 % of all material consumption, including fossil fuels, is currently being avoided as a result of recycling, waste prevention and eco-design policies; the maximum potential using the existing technology is estimated to be 10–17 %." (EC, 2011)
16	Recovered Materials Influences Employment	Increasing existing material recovery activities and expanding into new sectors generate additional employment opportunities. According to an impact assessment accompanying a legislative proposal[4], "about 120 000

[4] Http://ec.europa.eu/DocsRoom/documents/15949

		jobs could be created thanks to recycling of bio-waste in organic-based fertilisers." (EC, 2017a)
17	Resource Consumption Influences GHG Emissions	The extraction of natural resources generates direct emissions from the extraction activities themselves and extraction related energy use (UNEP, 2010). A study in Ghana suggests that a 1% increase in natural (fossil) resource extraction increases GHG emissions by 0.46%-0.51% (Kwakwa, Alhassan, & Adu, 2018). Energy-related GHG emissions depend on the fuel carrier used to produce energy and the technological standard (e.g. carbon capture) of the power plants (Fraunhofer ISE, 2013). The IEA publishes an annual report on energy related GHG emissions (e.g. (IEA, 2017).
18	End Of Life Materials Influences Material to Landfill	The amount of resources and products consumed drives, depending on the lifetime of the products, the amount of waste generated and hence the amount of resources that end up on landfills (OECD, 2013). In 2014, around 196 million tons, or 25% of EU-28's municipal waste, was landfilled (Eurostat, 2017a).
19	Recovered Materials Influences Waste Landfill	Sourcing raw materials and valuable resources from waste streams effectively reduces the amount of waste that is landfilled (OECD, 2013).
20	Material To Landfill Influences Well-Being	"Living in the vicinity of a landfill can represent a risk for health of residents because they may be exposed to pollutants from landfill through different pathways: the inhalation of substances emitted by the site, the contact with water or polluted soil, directly or through the consumption of products or contaminated water." (WHO, 2015). Suggested health impacts of landfills are birth impacts, respiratory disease and exposure to cancerogenic materials and excess cancer, such as pancreas, larynx, liver, and kidney cancer (Dolk, et al., 1998; Elliott, et al., 2009; Porta, Milani, Lazzarino, Perucci, & Forastiere, 2009; Mattiello, et al., 2013).

<table>
<tr><td>21</td><td>Material To Landfill Influences GHG Emissions</td><td>“The airtight conditions of landfill sites mean that materials, in particular biodegradable waste, cannot decompose fully and, in the absence of oxygen, give off methane, a dangerous greenhouse gas.” (EU, 2010)</td></tr>
<tr><td>22</td><td>Material To Landfill Influences Taxation (For Public Services)</td><td>The amount of waste sent to landfill increases the amount of waste to be managed by the public sector and hence increases management costs that need to be covered. “The costs associated with various waste management options are both financial (collection, disposal fee), as well as environmental. Together these costs make up the social cost of different waste management options.” (DEFRA, 2011)</td></tr>
<tr><td>23</td><td>Taxation Influences Resource cost</td><td>Imposing a tax on raw materials or components leads to an increase in price, which increases resource cost above the baseline value. As a consequence, the total cost of production increase, which might increase the price of the final product. The implementation of a ‘Carbon Tax’ or ‘Cap and Trade’ schemes for example would increase the cost of emission intensive resources (Arinez, et al., 2010).</td></tr>
<tr><td>24</td><td>Taxation (For Public Services) Influences Profits</td><td>Everything else equal, imposing an additional cost that businesses need to consider in their operations increases the total operation costs and hence reduces profits. (OpenStax, 2014)</td></tr>
<tr><td>25</td><td>End Of Life Materials Influence Incineration</td><td rowspan="2">The European Commission (2017e) outlines in its waste-to-energy guidance document for a circular economy that it is critical to plan waste incineration capacity with an eye on current and future recycling rates to ensure the right allocation of capital to either activity. “The transition towards a circular economy requires striking the right balance when it comes to waste-to-energy capacity for the treatment of non-recyclable waste. This is critical to avoid potential economic losses or the creation of infrastructural barriers to the achievement of higher recycling rates.” (EC, 2017e)</td></tr>
<tr><td>26</td><td>Recovered Materials Influences Incineration</td></tr>
</table>

27	Incineration Influences Energy Generation	"Waste-to-energy is acknowledged to be a necessary tool to move towards a more sustainable circular economy as it helps avoiding landfilling and generates energy." (EC, 2017c)
28	Energy Generation Influences Resource Consumption	Energy generated on-site or recovered from waste streams can be used instead of grid electricity. This reduces the need to expand power generation capacity and contributes to reducing the extraction of fossil fuels for power generation.
29	Incineration Influences GHG Emissions	"[I]mproving the energy efficiency of waste-to-energy processes and promoting those processes which combine material and energy recovery can contribute to decarbonising key sectors such as heating and cooling or transport and to reducing greenhouse gas emissions from the waste sector. For instance, diverting one tonne of biodegradable waste from a landfill towards anaerobic digestion to produce biogas and fertilisers can prevent up to 2 tonnes of CO2 equivalent emissions." (EC, 2017e, p. 8) "It important to stress that the waste hierarchy also broadly reflects the preferred environmental option from a climate perspective: disposal, in landfills or through incineration with little or no energy recovery, is usually the least favourable option for reducing greenhouse gas (GHG) emissions." (EC, 2017e, p. 4)
30	GHG Emissions Influence Resource Cost / Carbon Tax	The implementation of a 'Carbon Tax' or 'Cap and Trade' schemes would increase the cost of resources (Arinez, et al., 2010).
31	GHG Emissions Influence Well-Being	GHG emissions can have detrimental effects on human health and have various negative impacts among which are respiratory diseases, loss of work days and non-fatal heart attacks (EPA, 2013).
32	Well-being Influences Behavioral Change	This causal link captures the consequences of environmental degradation (e.g. air, water, noise pollution) on the behavior of consumers, or the affected population in

		general. When humans are exposed to negative stressors, they are more likely to change behavior towards more beneficial/sustainable patterns.
33	Taxation Influences Behavioral Change	"[C]osts linked to legislative compliance, such as for wastewater treatment, are driving water use reduction up the agenda of manufacturing businesses." (Sachidananda, Webb, & Rahimifard, 2016). In addition, the cost related to wastewater taxation provides a strong incentive to reuse process water (McDonald, 2005)
34	Behavioral Change Influences Responsible Consumption	"Although the concept of circular economy focuses more on industry and the supply side, consumers are an important part of the equation. In addition to industry needing to recover products and materials for remanufacturing, other forms of innovative businesses and consumption (Hobson & Lynch, 2016) are needed for circular economy to thrive. Examples of such innovative businesses for consumer include shared use of assets (car-sharing, power tools, etc.) and results-oriented services (lighting rather than light bulbs) (Tukker, 2015). This is warranted through the idea that consumers embrace access and use of services instead of owning products as such (Tukker, 2015; Hobson & Lynch, 2016). Also, diverse repair and refurbishing services are seen as a central way to prolong product life and to narrow the throughput of materials in economy (Riisgaard, Mosgaard, & Overgaard Zacho, 2016). Such innovative services offer opportunities for sustainable growth, and jobs alike." Text segment from (Repo & Anttonen, 2017)
35	Behavioral Change Influences Product Sharing	
36	Behavioral Change Influences Product Reuse	
37	Product Reuse Influences Repair, Refurbish	The reuse of products required repair and refurbishing, and can contribute to achieving the critical mass necessary for development of a repair and refurbish industry.
38	Repair, Refurbish, Reuse Influences Product Reuse	End of life material recovery strategies such as repair, refurbish or reuse increases the quantity of goods that can be reused and the reduces the amount of end of life materials.
39	Repair, Refurbish, Reuse Influences Employment	Studies have emphasized that for every percentage point reduction in resource consumption globally, nearly

		100,000– 200,000 new jobs can be created." (Nederland Circulair!, 2015) "While the recycling sector will be responsible for a substantial number of these jobs created, reuse through the repair and remanufacturing of broken and obsolete equipment is estimated to generate significantly more jobs compared to landfilling or recycling" (Dervojeda, Verzijl, Rouwmaat, Probst, & Frideres, 2014).
40	Product Reuse Influences Product Lifetime	Reuse and repair is one of the key strategies to extend the lifetime of goods, which is central to the circular economy concept. (EEA, 2016a)
41	Product Sharing Influences Product Lifetime	"In the public debate, collaborative consumption — more commonly known as the sharing economy — is seen as a contributor to a circular economy. The assumption is that shared use of assets leads to an increasing utilisation of existing products and consequently to a lower demand for new products. A market study on car sharing in Europe, for example, predicts that car sales will be 182 000 units lower (or 1.3 % of projected total car sales) due to car sharing in 2021 (Boston Consulting Group, 2016)." (EEA, 2017)
42	Responsible Consumption Influences Product Lifetime	"[A] rising demand for "green" products can be seen, along with a widespread willingness to switch to environmentally friendly alternatives. In particular, there is a growing willingness to opt for alternatives that do not mean "doing without" but instead represent added value for the individual and at the same time can bring about cost savings. That includes, for example, choosing to cycle to work each day rather than driving, which can also have positive health benefits." (BMBU, 2016). Responsible consumption hence implies that the way we consume is important, which extends to the development of long-term thinking concerning goods and services. The design and use of products, and their maintenance over time (i.e. repair, reuse) can have significant impacts on its longevity.

43	Product Lifetime Influences Demand	Circular economy practices aim to extend the lifetime of products and thereby to reduce the amount of waste. This implies a reduction in demand for new products through the extension of the lifetime of products. “[E]xtending product life by repair and reuse 'slows' demand and sales, which conflicts with prevailing business models of maximising sales.” (EEA, 2015). In addition, “[t]he re-use of products or materials such as clothes and furniture that would otherwise become waste has social, economic and environmental benefits, creating jobs and making products available to consumers who could not necessarily afford to buy them new.” (EU, 2010)
44	Pubic Incentives Influence Renewable Energy Use	« [P]olicy support continues to encourage significant investment and low costs through economies of scale. The number of countries with renewable energy targets and policies increased again in 2014, and several jurisdictions made their existing targets more ambitious — including a rising number with 100 percent renewable energy or electricity targets. As of early 2015, at least 164 countries had renewable energy targets, and an estimated 145 countries had renewable energy support policies in place.” (KPMG, 2015)
45	Public Incentives Influence Resource Efficiency	“[R]ecent research by three economists (two from Harvard and one from the London Business School) suggesting that sustainability initiatives can actually help to improve financial performance. The researchers examined two matched groups of 90 companies. The companies operated in the same sectors, were of similar size, and also had similar capital structures, operating performance, and growth opportunities. The only significant difference: one group had created governance structures related to sustainability and made substantive, long-term investments; the other group had not.” (IISS, 2016, S. 7)
46	Recycling Infrastructure Influences Recovered Materials	“Municipal solid waste is increasingly being diverted from landfills and kept in the economy through recovery or recycling. The share of material being recovered from

		municipal waste for recycling or composting has increased from 18% in 1995 to 33% in 2009." (OECD, 2013, S. 10)
47	Taxation Influences Disposable Income	Fees or taxation for the use of landfills and the provision of wastewater treatment services and facilities. These fees impose an additional cost that reduces the amount of money that could be spent otherwise (DEFRA, 2011; EC, 2016b).
48	Renewable Energy Use Influences GHG Emissions	The generation of energy from renewable sources such as solar, wind or hydropower does not create CO2 emissions, which indicates that increasing the share of renewable technologies contributes to reductions in total GHG emissions (EEA, 2017). On the other hand, from a lifecycle perspective, renewable energy technologies are not entirely carbon free, and the production of these technologies can be more carbon intensive than that of conventional technologies (Amponsah, Troldborg, Kington, Aalders, & Hough, 2014).
49	Renewable Energy Use Influences Employment	"Renewable energy has a demonstrated job creation effect. For example, energy created through solar photovoltaic cells, landfill gas, or biomass plants have a higher number of jobs created per unit of energy produced than energy produced through conventional sources. The positive job creation effect of renewable energy is a result of longer and more diverse supply chains, higher labour intensity, and increased net profit margins." (ILO, 2014) "Renewable energy is already contributing to job creation in many of these markets. In the specific case of the United States, solar generating capacity represents only slightly more than 1% of the total power capacity (coal at 26%). However, solar workers are already twice as numerous as those in the highly automated coal industry" (IRENA, 2017)
50	Eco-design Influences Material Efficiency	"Eco-design can deliver products that are more durable and longer lasting and easier to repair, upgrade and remanufacture; or that are easier to disassemble so their

51	Eco-design Influences Product Lifetime	components and materials can be reused or recycled. It leads to greener products that consume less energy and resources during manufacture, generate less waste and pollution at their end-of-life stages, incorporate no hazardous materials, create new markets for secondary raw materials, and open up new business opportunities that create jobs." (EC, 2017f)
52	Cascade Use Influences Material Efficiency	Cascading use of products increases the lifetime of resources and conserves resources within the consumption cycle by reusing it across the value chain. The Ellen MacArthur Foundation uses the example of textile for the description of their 'power of cascade use' principle of the Circular Economy. (Ellen MacArthur Foundation, 2015) "[C]otton clothing is reused first as second-hand apparel, then crosses to the furniture industry as fibre-fill in upholstery, and the fibre-fill is later reused in stone wool insulation for construction—in each case substituting for an inflow of virgin materials into the economy—before the cotton fibres are safely returned to the biosphere." (Ellen MacArthur Foundation, 2015, S. 8)
53	Cascade Use Influences Product Lifetime	
54	Refuse Influences Demand	The refuse strategy reduces the demand for natural resources by either reducing the demand for an existing product by eliminating the function provided by the product (i.e. phasing out) or introducing a more sustainable product to deliver the same function. (Potting, Hekkert, Worrell, & Hanemaaijer, Circular economy: Measuring innovation in the product chain, 2017)

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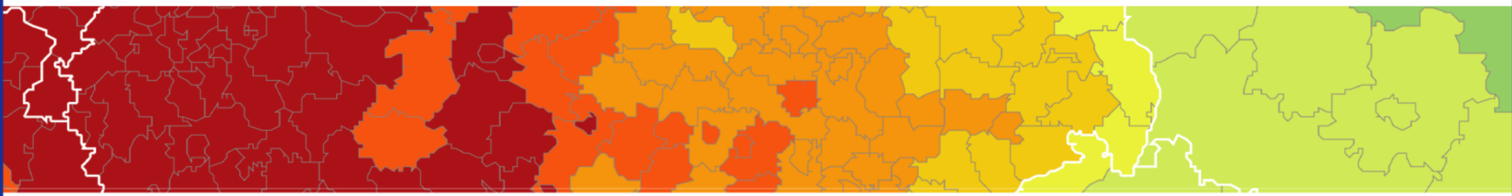

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