E4S
Enterprise for Society

UNIL | Université de Lausanne
HEC Lausanne
IMD
EPFL

Bending the Line:
Moving Towards a Circular Economy

E4S White Paper

November 2021

Bending the Line: Moving Towards a Circular Economy

E4S White Paper

Johannes Buggle, Paula Cacault, and Jean-Pierre Danthine

First version: June 2021

This version: November 2021

Enterprise for Society (E4S) is a joint venture of the University of Lausanne through HEC Lausanne, IMD and EPFL, under the stewardship of its College of Management of Technology, with the mission of spearheading the transition towards a more resilient, sustainable, and inclusive economy. E4S is dedicated to train the next generation of leaders, inspire economic and social transformation, and activate change by strengthening start-ups and boosting innovation.

gesda The project was conducted in the context of a partnership with the Geneva Science and Diplomacy Anticipator (GESDA).

Cover Photo from PickPik.

Table of Contents

Executive Summary

English

The world is today operating in a linear economy that extracts natural resources, produces energy or goods which are disposed in the form of pollution or waste. This “take, make, waste” system has generated prosperity and wealth in many parts of the world, but has also polluted the planet and the atmosphere. The consequences are climate change, the degradation of the environment, and loss of biodiversity. To avoid environmental catastrophes, there is an urgent need for a rapid transition away from the linear economy towards sustainable economic systems.

The circular economy offers such an alternative. In its ideal form, a circular economy is a regenerative economic system that uses renewable energy and resources, reuses materials and products as long as possible, and recycles resources rather than disposing them as waste. This report analyzes the necessary conditions for a move towards a circular economy and examines government policies that can foster the transition towards such a regenerative economy.

Français

Le monde fonctionne aujourd'hui selon une économie linéaire qui extrait des ressources naturelles, produit de l'énergie ou des biens qui sont disposé sous forme de pollution ou de déchets. Ce système de "extraire, fabriquer, gaspiller" a généré prospérité et richesse dans de nombreuses régions du monde, mais a également pollué la planète et l'atmosphère. Les conséquences sont le changement climatique, la dégradation de l'environnement et la perte de la biodiversité. Pour éviter les catastrophes environnementales, il est urgent d'opérer une transition rapide de l'économie linéaire vers des systèmes économiques durables.

L'économie circulaire offre une telle alternative. Dans sa forme idéale, l'économie circulaire est un système économique régénérateur qui utilise des énergies et des ressources renouvelables, réutilise les matériaux et les produits aussi longtemps que possible, et recycle les ressources plutôt que de les éliminer comme déchets. Ce rapport analyse les conditions nécessaires à l'évolution vers une économie circulaire et examine les politiques gouvernementales qui peuvent favoriser la transition vers une telle économie régénératrice.

Deutsch

Die Welt von heute ist dominiert von einem linearen Wirtschaftssystem, das natürliche Ressourcen extrahiert, Energie oder Güter produziert, die in Form von Verschmutzung oder Abfall entsorgt werden. Dieses "Entnahme, Verarbeiten, Entsorgen" System hat in vielen Teilen der Welt Wohlstand und Reichtum gebracht, aber den Planeten und die Atmosphäre verschmutzt. Die Folgen sind Klimawandel, Umweltzerstörung und der Verlust der Artenvielfalt. Um Umweltkatastrophen zu vermeiden, ist ein schneller Übergang weg von der linearen Wirtschaft hin zu nachhaltigen Wirtschaftssystemen dringend erforderlich.

Die Kreislaufwirtschaft bietet eine solche Alternative. In ihrer Idealform ist eine Kreislaufwirtschaft ein regeneratives

Wirtschaftssystem, das erneuerbare Energien und Ressourcen nutzt, Materialien und Produkte so lange wie möglich wiederverwendet und Ressourcen recycelt, anstatt sie als Abfall zu entsorgen. Dieser Bericht analysiert die notwendigen Bedingungen für einen Wandel hin zu einer Kreislaufwirtschaft und untersucht die staatlichen Maßnahmen, die den Übergang zu einer solchen regenerativen Wirtschaft fördern können.

1 Introduction

Once upon a time, the human population was much smaller than it is today, and the human lifestyle exerted much less pressure on the planet. In fact, until relatively recently the capacity of the earth and the atmosphere to regenerate did not make our "linear" economic system particularly striking or shocking. The linear economy extracts natural resources, produces energy or goods which are disposed after use in the form of pollution or waste. This "take, make, waste" system has generated and continues to generate prosperity in many parts of the world. In the original circumstances, the negative collaterals of extractive activities and the pollution and waste associated with production and consumption could be absorbed by the planet and the atmosphere. Moreover, the very local nature of economic interactions made the responsible management of the commons a necessity to which individuals and communities were alert. With the explosion in the world population, the growing intensity of activities associated with an increase in material well-being around the world and the emergence of international specialization rendering the management of the commons more difficult (notably because it impedes monitoring the impact of the associated negative externalities), the perspective has changed radically. It took us several decades to understand the dramatic impact of our economic activity on the planet in terms of climate change and environmental degradation. Estimates indicate that humanity is currently operating outside its boundaries in four out of nine areas (biodiversity, climate change, land system changes and biochemical flows, see Steffen et al., 2015). Our demand on the ecosystem largely exceeds the supply of renewable resources: Currently, 1.7 Earth planets are needed to satisfy global demand according to the Global Footprint Network, while in 2030 a second earth would be required to keep track with a growing global population that further increases the pressure on natural resources.

> IN ORDER TO STAY WITHIN THE PLANETARY LIMITS WE NEED TO STRIVE TOWARDS A CIRCULAR ECONOMY.

It is apparent today that such a linear economy is a dead-end and that in order to stay within the planetary limits we need to strive towards a circular economy. In its ideal form, a circular economy minimizes humanity's impact on the environment by shifting towards renewable energy and resources, by intensifying resource use, and by recycling resources rather than disposing them as waste. Transitioning towards a circular economy is difficult, however. Past societal choices created path dependence and a lock-in in the linear economy characterized by complementary modes of production, consumption habits, and physical infrastructures. Leaving the linear economic model needs a significant coordination effort to align production and consumption patterns, as well as infrastructure investments, with the goal of reaching circularity.

A major hurdle to circularity is that the playing field between the linear and the circular economy is not level. In the current economic system, the right to pollute and to over-exploit resources is essentially free. As many environmental externalities are not priced in markets, producers and consumers do not bear the cost they impose on the environment and on current and future generations. They therefore have no incentives to "become more circular". Thus, the linear economy is linear primarily because of market failures and mispricing of goods in the absence of corrections for negative externalities. Neoclassical economics has long devised prescriptions to correct environmental externalities by pricing them using taxation or market-based instruments. Getting all prices right would move economies towards circularity but proves to be very difficult in practice.[1]

IN THE CURRENT ECONOMIC SYSTEM, THE RIGHT TO POLLUTE AND TO OVER-EXPLOIT RESOURCES IS ESSENTIALLY FREE.

Price systems for emissions such as carbon have been implemented in several parts of the world in recent years. Putting a price on carbon is important, as carbon emissions are the major driver of global warming. However, carbon emissions are only a part of the global economies' environmental impact. Resource extraction and current production and consumption modes also affect the diversity of the biosphere, the quality and sustainability of essential resources such as water, and the Earth's biochemistry. Transitioning towards a circular economy therefore requires a coordinated "big push" of substantial policy interventions centered around correcting the prices of crucial environmental external effects, supported by additional policies that regulate resource use and recycling and that target consumer behavior directly.

In this report, we analyze the necessary conditions for a move towards a circular economy and examine government policies that can foster the transition towards such a regenerative economy. Section 2 describes the environmental burden associated with the linear economy. Section 3 discusses the main features of the circular economy and the barriers to the circular transition. In Section 4 we place the circular economy in a global context, and in Section 5 we discuss policy interventions that might prove necessary to permit circularity transition. Section 6 concludes.

2 The Linear Economy and its Environmental Impact

The linear economy that we know at least since the industrial revolution is characterized by a "take, make, waste" mentality. Resources are extracted, energy and goods are produced and disposed at the end of their lives. Growing economies and population have steadily increased the demand for resources and in a sense "created" the negative externalities we now need to price or

[1] Whether this would suffice to achieve full circularity will be discussed in Section 5.

eliminate. For example, it is estimated that a safe limit for atmospheric carbon concentration is below 350 ppm (Steffen *et al.*, 2015.) As long as carbon concentration were below this limit (this was the case for the entire history of the planet until the late 20th century[2]) the shadow price of these emissions was zero and the absence of a market or a tax was not a problem. While in 1900 6 billion tons of materials such as minerals, biomass resources, non-metallic minerals, and fossil fuels were extracted globally, extraction rose to 85 billion tons in 2015, and it is projected to double by 2050 (European Commission Raw Materials Scoreboard, 2018). The demand for other essential resources, such as clean water, has been rising as result of a growing world population, too, and is expected to grow further in the future.

GROWING ECONOMIES AND POPULATION HAVE STEADILY INCREASED THE DEMAND FOR RESOURCES.

In a linear economy, most inputs are lost in the form of emissions and waste. Waste creation, from food waste to packaging has exploded because of growing production and consumption. The surge in plastic waste is exemplary of the linear economy. While plastic production increased from 2 million tons in 1950 to 381 in 2014, only 20% of all plastic is currently recycled, and thus most of the energy and material inputs that go into plastic production are wasted.[3] Besides waste creation, emissions have been on the rise since the industrial revolution to satisfy the demand for energy. While in 1950 about 5 billion tons of CO2 were emitted globally, 70 years later global carbon emissions have increased to over 36 billion tons a year. The largest global emitter, China, emits almost 10b tons of CO2 every year.[4]

2.1 The linear economy has pushed the planet out of its boundaries

The linear economy has become unsustainable and has placed a huge burden on the environment. It contributes to rising global temperatures, environmental degradation, and a loss of biosphere. Global temperatures might increase by up to 5 degrees Celsius by the year 2100 if greenhouse gas emissions continue unabated.[5] Climate change will lead to melting of the icecap and rising sea levels, already increased the risks of draughts, water scarcity, and extreme weather, which affect especially the poorest parts of the world, and contributes to the extinction of animals and plants. It is estimated that species extinction rates are today 1,000 times higher than the baseline extinction rate (i.e., the natural extinction rate without humans) and are projected to rise further in the future (De Vos et al., 2015). Similarly, the rate of deforestation has increased significantly. Since 1992, the Amazon rainforest for example has lost one sixth of its area. Out of 18 areas in which nature is contributing to humanity, 14 have been declining since the 1970s, such as pollination and dispersal of seeds, regulation of air and water quality, and habitat creation and maintenance (see Dasgupta, 2021).

Environmental scientists have developed the concept of planetary boundaries that demark a safe operating zone for the human species. If humanity operates outside of these boundaries, there is a high risk of triggering tipping points which will lead to irreversible damage to the

[2] Information on carbon concentration from climate.gov. In the last 800,000 years, carbon concentration fluctuated at levels between 150ppm to 300ppm until the advent of industrialization.

[3] See Our World in Data.

[4] See Our World in Data.

[5] See the News Feature in Nature.

environment and other catastrophic consequences. From an economic perspective the notion of planetary boundaries is important because it defines the frontier beyond which a collateral output of human activity becomes (or is expected to become) a “bad” and deserves to be priced (or constrained with other means) as such.

CURRENTLY, FOUR OF THE NINE PLANETARY BOUNDARIES HAVE BEEN CROSSED.

Currently, four of the nine planetary boundaries have been crossed (see Figure 1): Biosphere integrity (loss of biodiversity), biochemical flows, climate change and land system change are under high risk (Steffen *et al.*, 2015).[6] The boundaries are interdependent as increasing the risk in one area can have consequences for another. Deforestation, for example, which is part of biosphere integrity, also exacerbates climate change because of reduced carbon storage in trees. The pressure on the environment is projected to increase further in the future, as the world population is rising, and as developing countries want and need economic growth to escape poverty. At the global level, this creates a dilemma between the desire to expand economic activity for a large part of the global population, and the need to restrict the use of resources and humanity’s environmental impact.

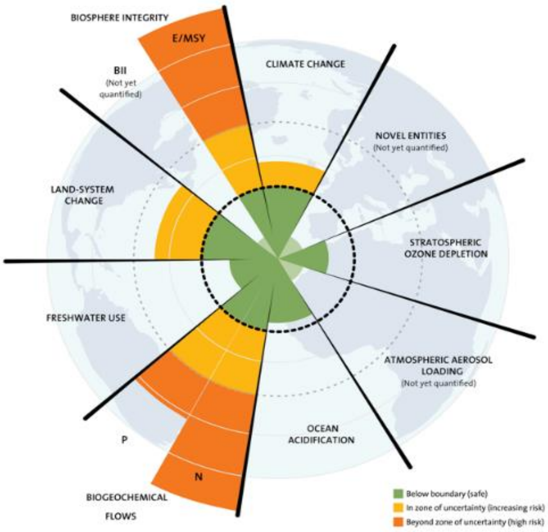


Figure 1: Planetary Boundaries (Steffen et al., 2015)

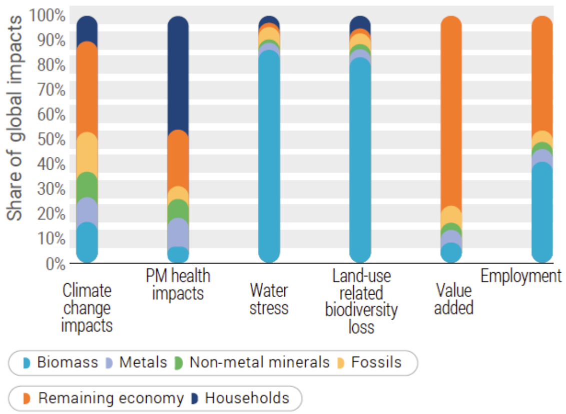
2.2 Resource use is a at the heart of the problem

The extraction and processing of resources have large environmental consequences. According to the Global Resource Outlook (IRP, 2019), about 90% of biodiversity loss as well as half of the world’s carbon emissions can be traced back to resources (see Figure 2). The highly energy-intensive extraction of biomass, metals, non-metal minerals and fossils contribute to climate change. By far the biggest impact on biodiversity and water stress is caused by biomass resources. This implies that resources should be the focus of policies that address climate change and biodiversity loss and calls for limitations to the extraction of primary resources and a more intense use of resources.

Thus, living within the planetary boundaries requires to curb resource extraction primarily because of the detrimental effects their usage has

[6] Raworth (2017) proposes to add a second interior circle to the planetary boundaries which demark social boundaries. Societies should aim to operate within the outer planetary and inner social boundaries. Due to the resulting shape of this safe and just space for humans, the concept is called the Doughnut Economy.

for the environment. A sustainable economy will not stop extraction entirely but limit it to a level that allows nature to regenerate itself. For renewable resources, such as fishes in the ocean, that means that their exploitation should be restricted to an amount that allows the resource, i.e., the stock of fish, to renew itself. For non-renewable resources, such as copper or fossil fuels, this implies a limit too, but not because we are afraid of exhausting them soon, but because their extraction and use destroys the environment.



Data sources: Exiobase 3.4 (Exiobase, n.d.; Stadler et al., 2018), combined with land-use data from chapter 2 and impact assessment methods (Section 3.1). Reference year: 2011

Figure 2: Impact of resource extraction and processing (IRP, 2019)

From a policy perspective resource scarcity seems to be a more manageable problem, as scarcity is reflected in market prices. In market economies, a shortage of resources leads to increases in their price, automatically creating incentives for firms to use less resources, to recycle materials, and to search for alternatives. However, if the problem arises because the material extraction and use contribute to potentially irreversible negative environmental damage, the price reactions to perceived scarcities is not sufficient or appropriate. We are therefore experiencing a very different and possibly more difficult problem than the one of resource scarcity predicted by the Club of Rome in the 1970s. Rather than facing shortages, we are living in a world characterized by a surplus of too cheap resources, such as fossil fuels, that we should exploit with utmost moderation or leave in the ground because of their environmental impacts. This issue will not be solved by unfettered markets, as they fail to incorporate environmental effects. Government intervention is crucial to constrain resource extraction and increase the intensity of resource use.

2.3 Market failures in the linear economy

The linear economy is unsustainable because of market failures when planetary limits are exceeded. Market prices do not incorporate the entire costs of human activity on the environment and the wellbeing of current and, particularly, future generations. In fact, for many crucial environmental services, think of the pollination of plants by bees for example, no markets exist, with the consequence that these services have no market value and are not integrated in economic decisions. As a result, the level of production and consumption and thus the degrees of resource extraction and pollution are too high, and social welfare of present and future generations is not maximized. To get back to the example of bees, billions are dying each year because of air pollution and land conversion that result from human interventions, but the resulting economic (and non-economic) loss is unaccounted for. A clear case of the common good not being protected at potentially huge cost for us all.

THE LINEAR ECONOMY IS UNSUSTAINABLE BECAUSE OF MARKET FAILURES.

The market fails first because agents do not consider costs imposed on others and the environment today and in the future, for example by polluting the air. If polluters do not have to pay for these "negative externalities" that they impose on the environment, they have no incentive to change their behavior. Moreover, property rights over environmental and natural resources are not (or cannot be) defined or are incomplete. Therefore, many environmental resources, such as the oceans or the air, are public goods whose access cannot be restricted, and which suffer from free-riding and over-exploitation (the tragedy of the commons). Overfishing of the oceans, over-extraction of minerals, or excessive pollution of the air illustrate some of the consequences of the status of the environment as a public good.

Arguably, a second related source of market failure resides in the inappropriate weight that markets give to future generations (and to events very distant in the future). As emphasized by the Stern Review (Stern, 2006), the rate of return implicit in observed financial prices is probably too high to be considered a proper discount rate for long-term environmental considerations (i.e., markets place too much weight on the present). In essence, the linear economy is linear because of market failures and mispricing of goods that do not include a correct valuation of the environment today and in the future, that is, that do not reflect the proper value of the commons for the collectivity as a whole including future generations of humans.

2.4 Correcting environmental market failures

To correct environmental market failures and to change the behavior of producers and consumers, market and non-market-based solutions have been proposed, as well as rules, regulations and policies that target the behavior of agents directly. We discuss the most important ones in the section below.

1. Taxes and subsidies

A common prescription by economists to correct negative externalities is to impose a tax on harmful activities (Pigouvian tax). Facing "true" prices that incorporate a valuation of the harm done to the environment and others, (rational) agents would have incentives to produce and consume less, and to produce in alternative ways with new and cleaner technologies and recycled materials.

While in theory imposing Pigouvian taxes seems straight-forward, in practice their implementation may be difficult for several reasons: Foremost, putting a price on environmental resources services that are not traded on markets and therefore quantifying the effect of human activity on nature in monetary values is notoriously complex.[7] In particular, many effects of human action on the environment are not immediately observed, but their consequences are born in a future that is far away and uncertain. For example, carbon emissions stay in the atmosphere causing climatic change for many centuries to come. Relatedly, nature has an option value, i.e., a value arising from the possibility of using it in the future.

[7] On the one hand, the environment has a value for the economy as it provides resources and environmental services such as absorption of emissions. On the other hand, the environment also benefits human health and wellbeing, such as enjoying clean air or landscapes and animals which gives pleasure to humans. Therefore, besides its economic value, nature also has an amenity value, and moreover it has an intrinsic value (Dasgupta, 2021). A complete correction of all externalities should therefore consider all economic and non-economic costs. Valuing non-market external effects is inherently complex and requires non-market valuation methods such as assessing revealed or stated preferences of economic agents.

Therefore, prices need to be forward looking, but the long-term consequences of human actions today are very hard to assess and possibly subject to short-term biases.

The difficulties in valuing the environment can be illustrated by the complexity of pricing carbon. The social cost of carbon is meant to measure the economic harm from one additional ton of carbon emitted. But there is considerable uncertainty about the impact of one extra ton of carbon on the earth's planet as there is little solid consensus on the ultimate economic cost of one extra degree in the planet's atmosphere. Moreover, carbon price estimates crucially depend on how much society today values the future relative to the present. Different discount rates give rise to very different carbon prices: According to US estimates, a 5% discount rate leads to a social cost of carbon in 2030 of about 10 USD, while a discount rate of 2.5% leads to a social cost of carbon of 50 USD (see estimates by the US Environmental Protection Agency). Stern (2006) assumed an even lower discount rate of 1.4%.

Moreover, the scale at which governments would need to calculate taxes and impose them would be enormous. Thus, while Pigou taxes are the first option to look at, all the more because they have a pervasive effect – going in all the nooks and crannies of the economic system, they should probably be reserved for a few critical or obvious cases. Moreover, one must take account of the redistributive effects of Pigouvian taxes leading to frequent political resistance from the most-affected groups of society. The *Gilets Jaunes* movement in France provides striking evidence of the difficulty of implementing a tax on carbon.[8] The rejection of a CO2 tax included in a June 2021 popular vote can be read in the same light. Despite these difficulties, Pigouvian taxes have been used to correct environmental externalities, for example to reduce waste with landfill taxes, taxes for pollution of water (effluent charge), taxation of different sources of energy, or vehicle registration taxes.

An alternative to correcting negative externalities via Pigouvian taxes may be for policy makers to subsidize activities that have positive effects. For instance, providing alternatives to the goods or methods of production that generate those negative externalities, e.g., subsidizing research that could result in alternative sustainable products and means of energy, or developing renewable materials and goods. Offering sustainable alternatives increase the elasticity of demand (i.e., the reaction of demand to price changes) for goods with negative externalities and therefore the effectiveness of Pigouvian taxes. Clearly, as the environment is a public good that suffers from free-riding behavior leading to under provision and over-exploitation, there is a need for governments to step in and to invest in its protection.[9]

[8] Issues of social justice can arise in Pigouvian taxation particularly if some parts of population are hit harder by the correction of the externality via prices, such as was the case for the carbon tax in France. Poorer, more rural households depend on transportation by car and were more affected by an increase in fuel prices than richer, more urban households. Such effects on inequality are particularly dramatic if there are no affordable alternatives (e.g., an efficient public transportation network). The issue of using the tax proceeds to compensate the losers and make the introduction of the tax beneficial for all is therefore a central element of a policy aiming at correcting negative externalities.

[9] Many environmental services create positive externalities that are enjoyed by all citizens in the world, i.e., they are global. Rainforests, such as the Amazon rainforest, store large quantities of CO2 and are rich in biodiversity which benefits the entire human population even those that live outside the countries in which the Amazon is located (Brazil, Peru and Colombia). However, these countries pay for the conservation of the rainforest, either directly for the costs of conservation, or as opportunity costs because economic benefits of deforestation are lost if forests are protected. Therefore, it is justified and has been proposed (and stressed in the recent COP26) that the rest of the world should compensate the countries in which the global public good is located for their efforts to preserve and protect it (Dasgupta, 2021).

2. Market based instruments

Besides Pigouvian taxes, market-based instruments can be appropriate to correct negative environmental externalities. If property rights over the environment can be defined, and if transaction costs are not too high, then private negotiations can create a price for the externality (Coase Theorem). For example, markets for pollution and emissions allow the exchange of rights to pollute assigned by a government. As pollution allowances are exchanged, the market establishes a price for pollution and polluters internalize the negative externalities. Governments define an emission cap, i.e., a level of emissions that is compatible with a specific environmental goal and control the amount of total pollution by the allocation of pollution rights. Such cap-and-trade systems may be preferable to taxes if governments have better information about the optimal quantity of pollution rather than the optimal price. However, governments face uncertainty when setting a cap, for example there is uncertainty by how much global temperatures will increase when the CO2 concentration in the atmosphere doubles ("climate sensitivity"). Cap-and-trade can thus be used in a precautionary approach as it offers complete certainty over the total quantity emitted in an economy.

The EU uses a cap-and-trade scheme called the EU Emission Trading System in which rights to emit CO2 are traded. Currently (May 2021) the price per ton has passed 50 Euros. To attain emission levels compatible with the Paris goals it is estimated that the price needs to reach a range between 50 to 100 US dollars.[10] However, while carbon markets are in place in regions such as the EU, some US and Canadian states, the UK (since 2021), and China (since 2021), many countries do not have markets for carbon emissions and there is yet no global emission trading system. Besides trading of carbon emissions, cap-and trade schemes are used for trading air pollution (such as sulfur dioxide and nitrogen oxide) and water quality. Regarding biodiversity, a system of offsets works in a way that is similar to cap-and-trade systems. A cap on total biodiversity impacts can be imposed, that is often set at zero corresponding to the idea that no net loss in biodiversity should be tolerated. Individuals or companies that negatively impact biodiversity in one location are required to offset the same amount and type of biodiversity in another.

3. Command and control

Besides instruments that target economic incentives, command and control policies are rules and prohibitions to regulate the amount of pollution allowed, as well as the extent to which materials and resources can be exploited. Bans on single-use plastics are an example that regulate the material use. To protect eco-systems, governments can create protected areas that limit human's impact or ban the trade of plants and animals. Unlike taxes, command and control policies do not generate revenue for the government. Compared to market-based instruments, command and control policies are generally considered to be less cost-effective but they may be more politically acceptable notably because economic instruments may require large price increases to achieve environmental targets with important consequences in terms of inequality.

4. Behavior and social norms

An alternative to economic interventions is to target directly the behavior of consumers and producers. Research in psychology and behavioral

[10] According to a report by Commission on Carbon Prices featured in Reuters.

economics has shown that there exists an important gap between people's preferences and their actions in the realm of sustainability (White *et al.*, 2019). While consumers often state that they want to consume sustainably, they do not act in line with their preferences when making consumption choices. Peer effects and nudges that push consumers towards sustainable consumption alternatives can induce eco-friendly and sustainable behavior. Like command-and-control policies, policies that target behavior of consumers lower the need for Pigouvian taxation. This can have important positive distributional effects.

2.5 Summing up

In sum, correcting prices either via Pigouvian taxes or market-based solutions is possible but getting prices right is difficult and correcting *all* externalities via prices is probably out of reach. Valuing environmental impacts is complex, price signals may induce too slow reactions, are often politically resisted, and markets may not place sufficient value on the benefit of a better environment for future generations. Carbon pricing illustrates many of these problems. In markets where emissions are traded, such as in Europe, CO2 prices have been dragged at an excessively low levels by an excess supply of emission rights, plausibly the result of the lobbying of those concerned. They are still too low relative to the social cost of carbon, which as described above, is itself a very imperfect valuation of the true costs of emissions. To be compatible with the goals of the Paris agreement, CO2 prices would need to increase significantly (a review of the literature by Stiglitz *et al.*, 2017 concludes that the price per ton should be between 40 - 80 USD in 2020, and between 50 – 100 USD in 2030). Nevertheless, externalities for which a credible estimate of the external effects can be derived and those that can be internalized via markets, can be relatively easily corrected, and in a cost-effective way, via the price system. Evidence suggests that carbon pricing lowers CO2 emissions and induces low-carbon innovations (e.g., Gugler *et al.*, 2021; Cui *et al.*, 2018). Moreover, Pigouvian taxes raise revenues for governments and lower the need for other taxation (for example labor taxation). Therefore, economic instruments seem to be the first best solution to try to correct environmental externalities if credible estimates of the external effects can be derived.

However, transitioning rapidly towards economies that are fully sustainable is unlikely to be possible by relying on a limited set of price or market-based instruments. Correcting externalities with high impact is important but this should be combined with other policy measures. As many of today's infrastructure and lifestyle habits depend on past choices and are sticky (e.g., cities are built for cars, traditionally diets include beef), changing them is hard and calls for a concerted set of many simultaneous policy interventions, in addition to correcting prices. Rosenbloom *et al.* (2020) illustrate the need for a systemic approach rather than an isolated policy intervention in the context of mobility. Besides a move away from fossil fuels possibly achieved through carbon pricing, corresponding changes in city planning, investments in public transportation, changes in lifestyle such as working remotely, and different services offered by businesses (e.g., sharing) are also necessary.

The choice between the linear and alternative economic models can therefore be conceptualized in the context of multiple equilibria. Past societal choices created path dependence and a lock-in in an environmental harmful linear economy equilibrium characterized by complementary modes of production, consumption habits, and physical infrastructures. The linear economy is, however, only one possible equilibrium and alternatives exist, notably a circular or regenerative economy where resources are renewable, inputs recycled, and pollutions minimized. Moving towards such an alternative equilibrium requires a substantial coordination effort between agents to align production and consumption patterns, as well as infrastructure investments. A coordinated "big push" through a portfolio of concerted government interventions is crucial to overcome the lack of coordination between agents and to transition towards a new sustainable equilibrium.

3 Circular Economy: a Sustainable Alternative

If, in theory, *all* externalities were internalized with *perfect prices* and the economy had enough time to fully adapt to the new price structure, how would it look like? The answer is that the economy would be more circular than linear! If all environmental externalities are appropriately compensated by price corrections, agents would by definition take into consideration all the costs their actions impose on the environment today and in the future. The notion of perfect prices is purely conceptual however as they should fully respect the "property rights" of unborn generations. At first the prices of resources and of the most resource intensive final consumer goods would significantly increase since they would imbed all the environmental costs. Higher prices would incentivize producers to change their methods of production, extracting substantially fewer primary resources, searching for cheaper, alternative inputs, such as recycled materials or renewable sources of energy, and to drastically reduce emissions and waste. This adaptation process would lead to significant changes in relative prices with the less-resource intensive goods becoming more advantageous, possibly even in absolute terms as returns to scale in their production are exploited (an example already observable is the huge drop in the price of solar and wind energy making them competitive with fossil fuel-based energy). In contrast to a linear economy that takes resources, makes products, and disposes them at the end of their lives, an economy with perfect pricing would use cheap renewable sources of energy, keep materials in use, and minimize waste. Inputs and output would ideally be kept in a loop, and the economy would indeed be more circular than linear (see also EASAC, 2015).

IF *ALL* EXTERNALITIES WERE INTERNALIZED WITH *PERFECT PRICES* THE ECONOMY WOULD BE MORE CIRCULAR THAN LINEAR.

The concept of a circular economy (CE) puts resources at the center and promises to be a sustainable alternative to the linear economic system. In the following, we will describe the main characteristics of the CE, and some of the beneficial effects for the environment and the economy that have been highlighted in the literature.

The CE offers is a systemic approach to creating a sustainable economy. In its ideal form, the CE aims to be a regenerative economy which uses renewable inputs and sources of energy and in which waste production is minimized. Unlike the linear economy that is based on the concept of “take, make, waste”, the CE follows the 4R strategy: “reduce, reuse, recycle, and renew”. It is circular, because it uses renewable inputs and sources of energy, maximizes the product use and reuse by design, and recycles materials to avoid waste and pollution, see Figure 3. In its ideal form, all loops are closed, no materials or energy is lost, and no waste is created.

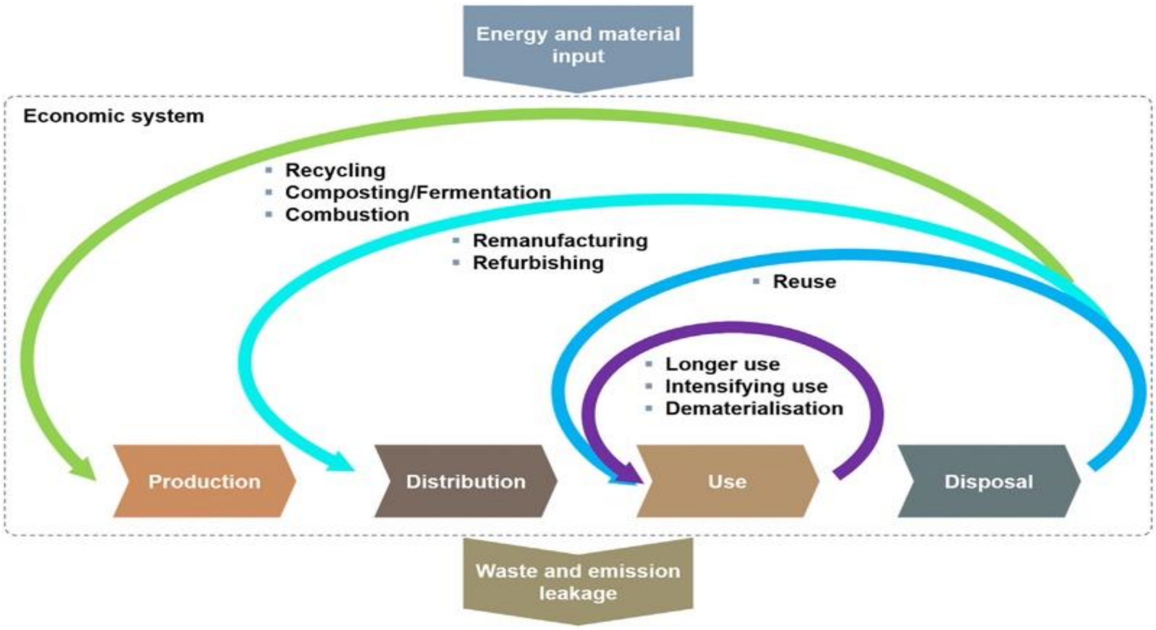


Figure 3: The Circular Economy (Geissdoerfer et al., 2020)

3.1 Principles of a CE

The three main principles of the CE are i) to design out waste and pollution; ii) to keep products and materials in use as long as possible; and iii) to regenerate nature (Ellen MacArthur Foundation, 2019).

1. Design out waste and pollution

In a CE, the design of products should facilitate reuse, refurbishment, or recycling. In particular, product design should make it easy to repair products and take out materials for further use. Ideally, production should prioritize inputs that are renewable (to emit less carbon), durable (to make products long lasting), possibly biodegradable (to avoid waste), as well as recycled materials (to reduce the use of virgin and high carbon materials). The CE also requires a move towards innovative business models. Instead of focusing on ownership models, the CE aims to use provide products as services for example in pay-per-lease models. Therefore, products should be designed to fit the sharing economy.

2. Maximize product and material use

To conserve the material and energy embodied in products, the CE aims at reusing products and their parts as long as possible. Reuse does not only lower carbon emissions associated with the production of new goods, but it also saves on materials and other resources and lowers the impact on the environment. Products should be repaired whenever possible, reused and redistributed, as well as refurbished. Besides reuse, recycling at the end of life of products is crucial, as it requires less energy than extraction of virgin materials and it avoids waste. In fact, recycling rates have been increasing in the last couple of years, but they are still quite low. In the European Union, for example, plastic recycling is at about 40%, recycling rates are higher for paperboard (80%) and glass (75%), but only 41% of electrical and electronic equipment are recycled.[11] New technologies based on artificial intelligence that automatically detect materials can make recycling more efficient.

Another way through which the use of products can increase is by changing consumption patterns and the concept of ownership. Products can be shared or rented rather than being owned.

3. Regenerate nature

Nature is regenerated as renewable resources are used and nutrients are returned to the soil through regenerative agriculture. Moreover, carbon is sequestered in soils and plants.

Thus, the CE goes beyond addressing climate change and carbon emissions. By targeting resource efficiency and waste creation more broadly, it aims to create a sustainable economy that protects nature and biodiversity, and that guarantees the long-term sustainability of resources.

3.2 A tale of three economies

In this subsection we briefly contrast 3 economies, the linear economy, the circular economy, and what we may call the sustainable economy (SE). The latter is the economy we know where all externalities have been internalized and all activities have fully adapted to the new price structure. The following differences can be identified:

1. In a CE, materials are kept in use. Rather than losing energy and material inputs in the form of emission and waste, the CE aims at closing loops by reusing them again as inputs. So does the SE. In the latter as well as in a plausible (but not the only) interpretation of CE, extraction of raw (renewable) materials is still possible, but only at a level that allows regeneration or is justified by long run considerations.

2. Compared to the linear economy, the CE in principle requires a shift in business models and concepts of ownership, as it focuses on providing goods as services. Moreover, product design needs to be adapted to maximize possibilities for reuse, repair and recycling. In the SE the same changes are not postulated but are likely to the extent that they are incentivized through the internalization of externalities and thus optimally designed to respect the planetary limits.

3. In a CE and in the SE the price system would be very different than it is now. In the current linear economy, prices do not reflect the cost that an economic activity creates for the environment and future generations ("external effects" or "externalities"). Since these externalities are not priced, the linear economy has a cost advantage over both the CE and the SE.

[11] See EEA.

In sum, the differences between CE and SE on the one hand and the linear economy on the other are substantial, while the differences between CE and SE are almost immaterial (but may exist due to ideological considerations) provided we accept that the ultimate objective of the CE is respecting the planetary limits. It is with that interpretation that we will refer to the CE (thus without making a difference with a SE) in the rest of our discussion.

3.3 Possible benefits of the CE for environment and economy

What are possible benefits of the CE for the environment and the economy? As the concept of the CE has been advertised primarily by international organizations and the business community, (quantitative) scientific research into the CE and its effect on environmental and economic outcomes is still in its early stages (Korhonen *et al.*, 2018). Regarding the effect on carbon emission, estimates by the Ellen MacArthur Foundation (2019) suggest that the CE applied to five key areas (cement, aluminum, steel, plastics, and food) could reduce emissions by 40% -45% until the year 2050. Other studies estimate that the CE could reduce greenhouse gas emissions from production of steel, plastics, aluminum, and cement by even 56% in Europe (Circle Economy, 2019).

> ESTIMATES SUGGEST THAT THE CE APPLIED TO FIVE KEY AREAS COULD REDUCE EMISSIONS BY 40% - 45% UNTIL THE YEAR 2050.

Moreover, proponents of the CE argue that is has a large potential for saving material costs. According to the WEF (2014), applying CE to manufacturing in the EU could lead to enormous savings up to US$ 630 billion. Consumer and businesses could also benefit as leasing and sharing of consumption goods, such as washing machine, can be profitable for firms and cheaper for consumers (Ellen MacArthur Foundation, 2012). The CE potentially also has positive effects for employment creation, as many activities that the concept promotes, such as repair, are labor-intensive. According to two reviews by the OECD (Lanzi *et al.*, 2020 and McCarthy *et al.*, 2018) the empirical evidence is limited but seems to suggest small positive effects of the CE on employment (effects range between 0 and 7% increase in employment due to CE policies). As one would expect, the effects are very heterogeneous across sectors and regions, as the extraction of raw materials will shrink, and new opportunities in the service sector providing waste management or repairs will increase.

For businesses, adopting a CE strategy could similarly save costs and potentially increase their resilience towards external shocks, in particular volatility in prices of raw materials (PWC, 2019). Moreover, there is potential for innovative products and business models, such as by creating new materials or designing eco-friendly products, or by developing businesses models that facilitate sharing or repair. By incorporating the CE as purpose in their business strategy, enterprises can also create a positive societal impact, and appeal to eco-conscious consumers that demand sustainable products. According to a study by PricewaterhouseCoopers (PWC, 2019) businesses with purpose have increased their brand valuation significantly compared to competitors in recent years.

3.4 Open questions

Quantitative impacts: While the quantitative impacts of a CE on the economy and the environment seem to be substantial, they should be taken with a grain of salt as many of the estimates are calculated by proponents of the CE, such as organizations, foundations, or business consultancies. Scientific research estimating the economic effects using frontier methodologies is lacking. The EASAC for example criticizes some of the calculations for their simplifications, which might overestimate benefits (EASAC, 2015). Relatedly, the focus of the CE proponents on the advantages for businesses and the economy comes with a lack of a precise understanding of how circular economic activities are benefitting the environment (Andersen and Martinsen, 2020). Open questions are for example which aspects of the environment a CE benefits besides removing greenhouse gas emissions (e.g., biodiversity), which policies are effective in moving towards more circularity and how progress towards a CE should be measured (see Section 5 below). A sound scientific evaluation of the effectiveness of CE policies and their economic and environmental gains are crucial for assigning priorities.

Physical limits: Another important question relates to the physical possibility and efficiency of the CE. While proponents of a CE seem to imply that circularity means 100% recycling rates, this seems neither possible nor economically optimal. Many resources that are crucial for human existence, such as food and water, can only be used once. Other materials lose quality when they are recycled, such as plastics. Research by Eriksen *et al.* (2018) suggest that with current technologies only 42% of the plastics loop can be closed. Even the most recycled material, paper, can only be recycled seven times.[12] However, other materials, such as glass, or metals, can be recycled an infinite number of times. Moreover, the socially optimal recycling rate for some materials might be below 100% if the marginal cost of recycling exceeds the marginal benefit at a recycling rate below 100%. More research into optimal recycling rates is needed. Economies might therefore not strive for "full" circularity but rather aim to maximize the circular part of economic activity. In so doing we should be guided by the concept of planetary limits which implies that the regenerative nature of the planet and the environment can be taken advantage of as long as we remain within the limits.

Barriers to CE: Why has a CE not yet been adopted, i.e., what are the barriers to adopting a CE (see Kirchherr *et al.*, 2017)? As we discussed above, the main barrier is indeed that prices are incorrect, giving the linear economy and linear goods a cost advantage over alternative, sustainable choices that are too expensive or not even available. Currently, it is still cheaper for most firms to use virgin rather than recycled materials. Moreover, markets for second-hand products and repair services are not well developed. Another important barrier is that established infrastructure, businesses models, and habits of consumers create a lock-in in the linear economy (EASAC, 2015). Shifting towards the CE requires significant coordination efforts between agents. Doing it alone when everyone else sticks to the old ways may be very expensive even if it would be beneficial and profitable for all to simultaneously change to the new ways. Changing business models takes time and money, often comes with high upfront investment costs, and not all products are suitable for sharing or leasing models. Traditional consumption patterns that demand an ever-growing amount and variety of cheap products, as well as sub-optimal recycling behavior are also important hindrances to moving to the CE. Other, potentially less important, barriers are related to missing technologies and an inappropriate regulatory framework.

[12] According to the US Environmental Protection Agency.

THE MAIN BARRIER TO A CE IS THAT PRICES ARE INCORRECT.

CE as a strategy for green growth: Should the CE be regarded as a development strategy? The concept of the CE is pushed especially by international organizations and policy makers, such as the EU or the OECD, that promote it as a way to achieve "green economic growth", and to a lesser extent by ecological economists who welcome it for environmental protection. The fundamental dividing line between the two camps revolves around the question whether environmental protection and sustained economic growth can be achieved in a CE. Many policy makers and neoclassical economists believe that economic growth can be both sustainable and green, while ecologists and ecological economists argue that there are planetary limits that bound human activity, and that even in a CE growth cannot be limitless.[13] The answer breaks down to the question whether harmful environmental impacts, such as GHG emissions or resource extraction, can be decoupled from growing incomes. Regarding resource decoupling, Hickel and Kallis (2020) do not find evidence for absolute decoupling on a global level. While possible in the short future under strong abatement policies, they argue that it will be physically impossible in the long-term to decouple resource use from growth under the assumption of annual growth rate of GDP of between 2 to 3%. Regarding impact decoupling (i.e., decoupling emissions from GDP growth), absolute decoupling seems feasible (Hickel and Kallis, 2020). Decoupling at a rate sufficient to reach the Paris agreement goals of 1.5-2 degrees global warming, however, crucially relies on the widespread adoption of negative emission technologies (Haberl *et al.*, 2020).

An important argument for why sustained growth of per capita incomes is difficult even in a CE is the rebound effect, i.e., falling prices because of greater resource efficiency that lead to more consumption and a more intense use of resources rather than a decline. Therefore, shifting the earth back into its planetary limits might require slowing down consumption even in a CE (Haberl *et al.*, 2020).

The bottom line is that rich developed societies (the case of emerging economies is the object of the next section) that take environmental protection seriously should become less obsessed with a growing GDP and be somewhat agnostic about the decoupling question. Living within the planetary limits is an imperative and material income growth is less relevant than increasing human welfare, including fulfilling employment and abundant leisure time, a fair distribution of economic gains, and the ability to enjoy quality public goods while protecting the natural capital on behalf of our children. To measure sustainable human welfare, alternative novel indicators, such as Green Domestic Product (see Danthine *et al.*, 2020, for Switzerland), Genuine Progress Indicators, or measures of Inclusive Wealth (Dasgupta, 2021), defined as the total stock of capital including produced capital, human capital, and natural capital, should be compiled and be the center of our focus.

[13] A similar view is shared in the Dasgupta Review arguing that *"[…] our economic possibilities are circumscribed – even if several steps removed via technological progress – by the Earth-System's workings. No amount of technological progress can make economic growth as conventionally measured an indefinite possibility."* (Dasgupta, 2021).

4 The Circular Economy in the Global Context

Most of the discussions around the CE focuses on applying it at a regional or local scale in developed countries. Is a CE best conducted at a local or global level? Which are the challenges and opportunities for global supply chains and developing countries?

Globalization moved significant parts of economic production from developed to developing countries in recent years. The transformation towards a CE could lead to reshoring and more local supply chains, thus erasing some of the gains of globalization. Essential circular activities, such as repair, refurbishment, or reselling might indeed be best conducted in the region where consumers are located. On the other hand, high labor costs in developed countries might disincentive labor intensive circular activities such as repair without policies aiming at correcting these economic incentives.

> THE CE COULD LEAD TO RESHORING AND MORE LOCAL SUPPLY CHAINS, THUS ERASING SOME OF THE GAINS OF GLOBALIZATION.

From an environmental perspective, the crucial feature of the CE is that loops are closed, no matter whether these geographic loops are global or local (WEF, 2014). Local loops can be advantageous because they avoid transportation costs and emissions from transportation, but they do not take advantage of international specialization. Therefore, a mixture between global and local activities seems economically optimal, especially in a CE that is powered by renewable energy. However, more detailed analysis of the optimal scale of different circular economic activities in terms of their environmental and economic costs and benefits is needed. Current practice reported by the WEF (2014) suggest that some activities that concern the maintenance of the product during its lifetime, such as repair, reuse, or reselling, are best conducted at the local level in proximity to the consumer because of convenience and faster turnaround. Goods for which costs of repair exceed their value, for example because of high labor costs will likely, be recycled. As producers and consumers are often located in different regions of the world, other activities such as refurbishment of products or the recycling at the end of the lifecycle can be conducted at either a local or global scale, for example along the supply chain or at the location of the original producers. Benefits of global trade can be reaped for very labor-intensive tasks, such as sorting of materials before they are recycled or reused optimally. These tasks are best performed where labor is cheap (EASAC, 2015). However, novel technologies such as robots and artificial intelligence can automatize significant parts of the sorting process and threaten the demand for human labor. For the CE to become truly global, a multilateral consensus should be established, and circular activities that may generate international trades such as recycling, or the trade of used materials and goods should be incorporated into international trade agreements.

Developing countries face two important risks of losing out in a transition to a CE. First, reshoring activities such as manufacturing would negatively affect income opportunities in the developing world (WEF, 2014). Second, developing countries might suffer substantial income losses from a reduction in extraction and exportation of primary materials on which they heavily depend. Finding alternative ways of income generation is therefore crucial, however whether it is possible to design the CE in an inclusive manner and to provide income opportunities for developing countries is an open question. Unfortunately, developing countries have been largely neglected in research on the CE. There are several ways, however, how the CE could contribute to economic development: First, if developing countries transition themselves towards a CE, then activities such as repair and recycling create novel local employment opportunities (Schröder *et al.,* 2019; Preston *et al.*, 2019). Second, developing countries have an advantage in labor intensive activities because the cost of work is low. Therefore, they could specialize in remanufacturing, reprocessing, or recycling which compared to raw material extraction uses even more labor. Estimates for Latin America suggest a net employment effect of 4.8 million jobs by 2030 if the circular economy is adopted (ECLAC/ ILO, 2019). The move towards a CE could thus push developing countries towards diversifying economic activities. Moreover, many developing countries have the advantage of being able to build on an already existing (informal) repair and refurbishment sector which needs further support (Preston *et al.*, 2019). In any case, the structural transformation towards a CE in less developed countries would be large and require financing and investment in technologies, a process that could be managed and integrated within development policy (Schröder, 2020).

DEVELOPING COUNTRIES HAVE BEEN LARGELY NEGLECTED IN CE DISCUSSIONS.

Regarding global supply chains, a CE could offer two advantages. First, supply chain resilience would be strengthened in a CE because firms would rely less on primary resources that are often characterized by volatile prices. Second, environmental benefits can be distributed and amplified throughout the supply chain, reaching regions of the world, as well as economic sectors, with little or no regulation (WEF, 2021). For example, producers facing carbon emissions restrictions for final goods in Europe will pass those to their suppliers along the supply chain. To monitor sustainability along the supply chain transparency and high-quality data is needed. New technologies, such as blockchain technologies that allow producers and consumers to track emissions and materials along the supply chain, can be instrumental in promoting circularity in the supply chain (WEF, 2021). For example, Mercedes-Benz has started a pilot study to track material flows and CO2 emissions with blockchain technology in the cobalt supply chain.[14]

[14] See Daimler.

5 Bending the Line: Policies to Transition to a Circular Economy

Estimates suggest that the world is currently only 9% circular, as most resources are neither renewable nor recycled but extracted and lost in the form of emissions and waste. This "circularity gap" has not been closing (Circle Economy, 2019). In the following, we analyze possible policy instruments to transition towards a CE. As the world is still locked-in the linear economy, fixing a few prices, while important, is unlikely to be sufficient.

Making the CE mainstream requires a "big push" composed of many different policy interventions, at the heart of which are corrections of prices. Government legislation, subsidies that spur innovation and the provision of alternatives, as well as interventions targeting firm and consumer behavior directly need to accompany economic instruments that adjust prices through taxation and market-based mechanisms. As discussed, while economic instruments have difficulties valuing perfectly environmental costs, they are efficient and key price corrections can be relatively easily implemented. Moreover, a substantial increase of environmental taxation at the expense of labor taxation would support the transition towards a CE, as many circular activities such as repair or remanufacturing are labor intensive. Devising CE strategies that emphasize environmental and economic opportunities and doing so at the national, regional, or municipality levels can provide a coherent policy framework based on local priorities and offer a positive narrative that motivates citizens and businesses to participate. As change is driven by preferences and choices of citizens, educational policy is an important lever to support this transition: a stronger focus of the educational system on fostering our connection to nature (Dasgupta, 2021), and on teaching sustainability and the principles of the circular economy across all ages, seems warranted.

MAKING THE CE MAINSTREAM REQUIRES A "BIG PUSH" COMPOSED OF MANY DIFFERENT POLICY INTERVENTIONS, AT THE HEART OF WHICH ARE CORRECTIONS OF PRICES.

Table 1 summarizes key policy interventions for different CE areas. The main priorities are as follows:

1. "Getting the prices right" is key to moving towards a low carbon future, to make recycled materials competitive with virgin materials, to incentivize repair and reuse, and to decrease the creation of waste in a CE.

Policy / Area	Renewable Energy & Resources	Recycling & Reuse of Materials	Reuse & Repair of Goods	Sharing of Goods	Eliminate Waste
Economic instruments	Pricing carbon	Pricing virgin materials	Tax exemptions for repair		Waste Taxation
Regulation	Ban certain non-renewable materials	Recycling targets Extended producer responsibility schemes	Right to repair		Landfill bans
Subsidies	Alternative materials		Modular design	Promote sharing platforms	
Behavioral	Lifestyle changes		Changing consumption patterns	Changing consumption patterns	Waste habits
Priority (based on planetary boundaries)	High	High	Moderate	Moderate	High

Table 1: Overview of Policies

2. Government regulation can aid the transition towards a CE by banning certain materials or by setting targets for recycled materials, by making producers responsible for recycling, and by strengthening the right to repair of consumers.
3. Governments can also subsidize circular innovation, such as alternative materials, circular design and sharing platforms.
4. Government policies can directly target the behavior of households, for example habits of transportation, diet, and consumption patterns.

With respect to assigning priorities, we regard the move towards renewable energy and resources as particularly important considering the impact of non-renewable fossil-based materials on climate change. Moving towards recycling and reuse of materials lowers primary raw material extraction which puts high burden on the biosphere and is therefore similarly crucial. Material extraction can be further lowered through reuse and repair and the sharing of goods. Finally, waste elimination through taxation and changing consumer behavior is another important lever to reduce pollution and degradation of the environment and should be of high priority.

We will detail the different policies in the following. As it will be apparent, an important limitation is the lack of research quantifying the environmental effectiveness of CE policies. Further research is urgently needed.

5.1 Policies

5.1.1 MOVE TOWARDS THE USE OF RENEWABLE ENERGY AND RESOURCES

Carbon Pricing. An important component of the CE is the shift towards renewable materials and energy. Fossil fuel use is the prototype of the linear economy. The extraction of fossil fuels has adverse effects on the environment, the resource is non-renewable and lost when fossil fuels are burned in the form of emissions. Currently, fossil fuels make up almost 80% of global energy production, and the burning of fossil fuels contributes to 87% of global CO2 emissions.[15] Moving towards renewable sources such as solar, wind, or hydro energy is both possible, and cheap. The price of energy from solar and wind energy is now significantly lower than energy from coal.[16] Once adopted, a CE can be powered entirely by renewable sources of energy as the sun and wind are limitless, they do not face any physical constraints.

To mitigate climate change, the transition towards renewable energy is particularly important and needs to be accelerated. Correcting economic incentives is key, in particular putting a price on carbon that incentivizes switching to renewable energy. Without a change in the price of carbon, important technologies such as carbon capture technologies that, as simulations show, are crucial to reach the Paris agreement goals of 1.5-2-degree global warming, will not be widely adopted as they are too expensive. The price of carbon needs to rise so that low carbon technologies become economically attractive.

Regulation. Governmental regulation can support the transition towards renewable inputs, by regulating and banning the usage of non-renewable and toxic materials, as well as the resulting products (see WEF, 2020). Plastics, for example, are made from oil, they are therefore not biodegradable, and can only be recycled two to three times at most. Many plastic products such as straws cannot be recycled at all. That is why many countries have started to ban single-use plastics in the last years, such as Canada (2021), Kenya (2017), or the EU (2021). Regulations are justified to foster behavioral changes that would be slow to materialize under pure price incentives. They may also permit reaching the desired changes without radical price changes that may pose problems from a distributional perspective.

Subsidies. Moving away from non-renewable materials needs to be supported by policies that subsidize the development of renewable and biodegradable materials. Subsidies are often necessary in the transition phase until new technologies reach a scale where scale economies deliver significant cost reductions and make them competitive with traditional production methods.

Behavioral Changes. Households are responsible for 72% of all greenhouse gas emissions (Dubois *et al.*, 2019). Household activities that generate high carbon emissions include heating, mobility, and diets (in particular meat-based diets). Government policy can raise awareness through information and change behavior through soft interventions such as nudges that target non-economic human motivations and social norms. For example, students that were told that their peers are using sustainable modes of transportation increased their use of sustainable transportation by a factor of five. Nudging, i.e., making sustainable choices the default option but keeping decision freedom is another strong tool to

[15] Taken from Our World in Data.

[16] Taken from Our World in Data.

change sticky consumption habits. For example, in Germany almost all households that moved into a residential building were green energy was the default choice sticked with it (White *et al.*, 2019).

5.1.2 Recycle materials at the end of life and use as inputs

To increase the efficiency of resource use, materials in a CE should be recycled and used as inputs into the production process. Most of the times, however, recycled materials cannot compete today with virgin materials: recycled materials are more expensive, they face skepticism regarding their quality, and the absence of markets on which secondary raw materials can be traded hinders their usage. *"Secondary raw materials face a number of challenges in competing with primary raw materials for reasons not only related to their safety, but also to their performance, availability and cost."* (see EU CE Action plan, March 2020). As material extraction puts a high burden on biodiversity, and to a lesser extent also climate change, reducing primary material extraction is crucial. Priority should be given to materials such as metals, aluminum, glass and others that can be recycled many times without significant losses in quality. Materials, such as plastics, that have inferior recycling potential should be avoided in production in the first place.

Taxing Raw Materials. An important policy to incentivize a more intense use of recycled materials is to correct prices for raw materials so that they incorporate the costs imposed on the environment. A tax on raw materials will lead to higher prices and level the playing field between virgin and recycled materials. Denmark, for example, had introduced a tax on raw materials in 1990, already.

Regulation. Governments can also set targets for recycled materials that make it compulsory for producers to use a certain fraction of recycled materials in final products. In addition, public policy can aid in the establishment of markets for secondary materials, for example through prioritizing secondary raw materials in public procurement (one of the goals of the CE Action Plan of the EU). Moreover, making producers responsible for the entire lifecycle of the product, in particular their collection and recycling at the end of life, can be achieved with extended producer responsibility schemes (EPR, see OECD, 2016). EPRs have the advantage that producers bear the costs (instead of municipalities and taxpayers), so that in theory they have incentives to design products that last longer and that are easier to recycle. The use of EPR's has increased since the late 1980s and, according to the OECD (2016) there have been 400 EPR systems in operation in 2013 globally, most of them in electronics, packaging, and tires. The quantitative impact of mandatory EPR on waste and recycling rates has not yet been well estimated, although some evidence suggests that EPR's do contribute to reduced waste (OECD, 2016).

Example. An example of the how EPR work is Auto Recycling Nederland (ANV) which organizes the take back and recycling of cars and batteries. According to the ANV, 88% of materials are recycled, and about 10% of the energy that went into the production of cars is recovered. Moreover, in Germany and other member states of the EU mandatory take back schemes for batteries have been implemented.

5.1.3 Increase the lifespan of products

Another path to decrease resource use and waste is to increase the lifespan of products through refurbishment, reuse, and repair.

Taxation. Tax policy can incentivize repair activities by reducing VAT on repair services or by decreasing labor taxation on labor-intensive repair services. Cheaper repairs would boost their usage and reduce the demand for new goods. A growing repair sector could have positive effects on employment. In 2017, Sweden, for example, has lowered taxes on repair of consumer goods from 25% to 12%.[17] Since 2008, Swedish citizens can also ask for a 50% deduction of labor costs associated with home repairs and maintenance. Unfortunately, the effectiveness of the Swedish tax reforms has not yet been evaluated.

Product life can be extended by reselling consumer goods which keeps energy and resources used in their production in the loop. As in the case of recycled raw materials, there is a lack of markets for secondhand and used products. Markets for used goods will appear if consumers find it profitable to buy used rather than new, for example because the prices for new goods are significantly higher at a level of quality that is comparable. Price corrections for new goods to account of attendant externalities and tax incentives for local (physical) stores that sell used goods could increase the availability of secondhand products.

Regulation. Including a "right to repair" into government legislation can further contribute to more repair activities. A right to repair allows consumers to repair consumer goods themselves, especially electronics, without having to turn to the original manufacturer. Producers must make spare parts and manuals easily accessible for consumers and third-party repair companies. A major barrier for repair is that consumer goods are not designed for being repaired in the first place. For example, unlike the most sold mobile phones manufactured by Apple or Samsung, few mobile phones, such as the Fairphone, enable consumers to change parts that are heavily used themselves, such as the display. Governments could therefore support the development of innovations in circular and eco-design, i.e., design that allows an easy separation and replacement of parts, through financial support and legislation.

Behavioral Changes. When making the decision to buy a new good rather than reuse or repair an already existing good, consumers do not only care about the good's functional value. Goods also have other values for consumers, such as emotional or social values. To simulate retention of products, research in psychology has proposed strategies that trigger the different values of consumers, for example through increasing emotional product attachment, enhancing motivation for product care, and reminding users of required care activities (van den Berge *et al.*, 2020).

Example. The fashion industry provides a good example for the emergence of a substantial secondary trade in goods. Consumerism and fast fashion have spurred textile production in recent years with large environmental costs. Textile production creates 20 per cent of global wastewater and 1o per cent of global carbon emissions (more than all international flights and shipping).[18] However, during 2020, secondhand fashion has been growing rapidly. This trend has been spurred partly by a change in consumer preferences, as younger generations, such as generation Z, value sustainability and turn away from fast fashion, coupled with technological improvements that make selling used goods online easy and convenient. Moreover, economic factors have been an important accelerator of the

[17] See WEF.

[18] See UN-Environment.

move towards second-hand fashion too because many consumers experienced tightened budgets during the Covid pandemic. With less money in their pockets, consumers turned towards cheaper secondhand items or sold part of their wardrobe that is unused. The direction in fashion seems to be going in the right way: In the US, the secondhand clothing market is forecasted to triple in value in the next ten years and could overtake fast fashion by 2029.[19]

5.1.4 Increase the use intensity of products through sharing

Supply of Sharing. Sharing resources between consumers increases the intensity with which they are used and therefore lowers demand for resources. For example, private transportation by car is inefficient as vehicles are parked 92% of the time (in Europe) and when they are on the road, they are mostly occupied by a single person (Ellen MacArthur Foundation, 2019). Rather than owning a car, households could share a car and use it only when needed. Sharing and product-as service models can significantly save on resources and lower the cost of access for consumers. Governments can promote sharing platforms (e.g., vehicle sharing, electronic equipment rental and sharing) through legislation and public funds, and support startups that develop innovative business models.

Changing Consumption Habits. The transformation from owning towards sharing needs to be supported by changing consumption patterns. Making sharing convenient by developing online sharing platform, by increasing the offer, by informing consumers about costs and benefits of sharing and/or by offering financial incentives for consumers who share rather than buy can be levers of new consumption habits away from private ownership.

5.1.5 Decrease waste

The CE strives for zero waste and in the waste management hierarchy, disposal is the least desirable option. Many of the policies discussed before that stimulate recycling, reuse, repair, circular product design, or that make producers responsible should contribute to decreasing waste and disposal of goods at the end of their lives. Still, a policy mix towards a CE should also target waste creation directly. This is particularly important as one of the most important challenges to the CE is biomass and food. Biomass refers to all products from animals and vegetables used as food, materials, or fuels, such as crops or wood. Among all resources that are extracted, biomass has the largest impact on biodiversity loss and water stress (IRP, 2019). Food production is also a major disruptor of the Earth's nitrogen cycle. Therefore, reducing biomass extraction is key for keeping the planet in its limits. However, a growing population demands more and more biomass resources, in particular food, while citizens of developed countries have an excess of food. Food waste in the EU amounts to 88 million tons (or 143 billion Euros) per year.[20] While parts of food waste can be recovered for energy production or as fertilizers, decreasing waste and overextraction of resources in the first place should be a priority.

Taxation. Environmental taxation can be used to target waste recovery and separation of waste. Landfill taxes paid by households might incentivize waste reduction and pay for the cost of waste management that communities undertake. Carattini *et al.* (2018) show that pricing garbage by the bag (PGB) can be highly effective. Analyzing

[19] See The Conversation and ThredUP.

[20] According to the European Commission.

the introduction of PGB in the Canton of Vaud, they find that it persistently decreased incinerated waste by about 40% and increased sorting and recycling of aluminum and organic waste by about 20%. While citizens initially resisted the implementation of the tax, after it was introduced, beliefs changed and acceptance of PGB increased significantly. By using waste taxation, the Canton of Vaud has achieved a recycling rate of close to 60% in 2019.[21] For comparison, its neighbor, the Canton of Geneva, the only canton in Switzerland without waste taxation, used non-economic instruments to spur recycling but achieved a recycling rate of just 50% in 2019.[22]

Regulation. Landfill bans are measures that regulate the disposal of certain wastes into landfill, as well as treatment prior to disposal. Many European countries have included bans into waste legislation for a diverse set of products and materials, such as tires, hazardous waste, or food and organic waste.

Behavioral Changes. Waste reduction policies can also be supported by campaigns that raise awareness and inform consumers about the problem of waste creation. Behavioral interventions that target social norms seem to be effective, too. For example, information stickers close to garbage cans telling people that most of their neighbors do not litter significantly reduced littering in the Netherlands from 5o% to 30% (OECD, 2017).

Example. Within a decade, South Korea has eliminated a large amount of food waste with a policy-mix of regulation, environmental taxation, and information campaigns. In 2005 Korea banned food waste in landfill. A couple of years later, Korea introduced special bags for food waste that were taxed (volume-based fee), which not only pays a large amount of the municipal costs of collecting and processing food waste but reduced waste creation further. Today, South Korea recycles 95% of all food waste.[23] Regulation and taxation policies were supported by campaigns that rose awareness for the issue of food waste (OECD, 2019). That a mix of regulation, bans and taxation is effective to reduce landfill and waste is confirmed from experiences in other countries, notably the Netherlands.

5.2 Circularity indicators

To measure the effectiveness of CE policies and to track progress in a CE there is need for circularity indicators. A shared agreement on indicators that guarantees comparability across nations and time as well as the availability of high-quality data are key.

Some important metrics are:

- Extent of emissions and waste produced;
- Recycling rates and the share of recycled materials in production;
- Trade in secondary materials and used consumer goods;
- Growth of the repair sector (e.g., number of repair shops, number of repairs conducted);
- Growth of the sharing economy;
- The number of jobs created in circular economic activities.

Besides, novel measures of welfare such as Green GDP, Inclusive Wealth and other measures of environmental accounting are important metrics

[21] Information from Vaud Statistics.

[22] Information from the Canton of Geneva.

[23] Information from the WEF.

to complement GDP as a measure of long-run progress and to track the sustainability of the CE.[24]

6 Conclusion

The linear economy is unsustainable and has pushed the planet out of its boundaries. Current production modes, consumption habits, and infrastructures are aligned with its “take, make, waste” mentality. The linear economy results out of the failure of markets to incorporate harmful environmental behavior into prices. Because of path dependence, bending the line towards a circular economy requires a concerted policy mix that corrects the “linear” prices of resources and goods, complemented with governmental regulation and subsidies as well as a shift in consumer behavior. More research effort is needed into different methodologies to value nature and the environment, as well as a sound evaluation of the most effective circular policies to establish good practices and to make the circular economy the mainstream economic system of the 21st century.

[24] A difficulty that all the indicators share is the economic valuation of nature, environmental services and other non—market services such as unpaid care. Progress needs to be made in environmental accounting to derive metrics that are as comprehensive as possible (i.e., they include a maximal number of environmental services), while being comparable across time and across regions.

References

Carattini, S., Baranzini, A., & Lalive, R. (2018). Is taxing waste a waste of time? Evidence from a supreme court decision. *Ecological Economics*, *148*, 131-151.

Circle Economy (2019). The Circularity Gap Report. Closing the Circularity Gap in a 9% World.

Cui, J., Zhang, J., & Zheng, Y. (2018). Carbon pricing induces innovation: evidence from China's regional carbon market pilots. In *AEA Papers and Proceedings* (Vol. 108, pp. 453-57).

Danthine, J.-P., Gallopin, C., & Petrencu, V. (2020). Green Domestic Product: Netting Greenhouse Gas Emissions from Gross Domestic Product. E4S White Paper.

Dasgupta, P. (2021), *The Economics of Biodiversity: The Dasgupta Review.* (London: HM Treasury)

De Vos, J. M., Joppa, L. N., Gittleman, J. L., Stephens, P. R., & Pimm, S. L. (2015). Estimating the normal background rate of species extinction. *Conservation biology*, *29*(2), 452-462.

Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., ... & Sauerborn, R. (2019). It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. *Energy Research & Social Science*, *52*, 144-158.

EASAC. (2015). Circular economy: a commentary from the perspectives of the natural and social sciences.

ECLAC/ ILO. (2019). *Environmental sustainability and employment in Latin America and the Caribbean Employment*. Situation in Latin America and the Caribbean, No. 19 (LC/TS.2018/85), Santiago, 2018

Ellen MacArthur Foundation (2012). Towards the CE. Economic and business rationale for an accelerated transition.

Ellen MacArthur Foundation (2019). Completing the Picture: How the CE tackles climate change.

Eriksen, M. K., Damgaard, A., Boldrin, A., & Astrup, T. F. (2019). Quality assessment and circularity potential of recovery systems for household plastic waste. *Journal of Industrial Ecology*, *23*(1), 156-168.

Geissdoerfer, M., Pieroni, M. P., Pigosso, D. C., & Soufani, K. (2020). Circular business models: A review. *Journal of Cleaner Production*, 123741.

Gugler, K., Haxhimusa, A., & Liebensteiner, M. (2021). Effectiveness of climate policies: Carbon pricing vs. subsidizing renewables. *Journal of Environmental Economics and Management*, *106*, 102405

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., ... & Creutzig, F. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. *Environmental Research Letters*, *15*(6), 065003.

Hickel, J., & Kallis, G. (2020). Is green growth possible? *New political economy*, *25*(4), 469-486.

IRP (2019). Global Resources Outlook 2019: Natural Resources for the Future We Want. Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H., Clement, J., and Cabernard, L., Che, N., Chen, D., Droz-Georget , H., Ekins, P., Fischer-Kowalski, M., Flörke, M., Frank, S., Froemelt , A., Geschke, A., Haupt , M., Havlik, P., Hüfner, R., Lenzen, M., Lieber, M., Liu, B., Lu, Y., Lutter, S., Mehr , J., Miatto, A., Newth, D., Oberschelp , C., Obersteiner, M., Pfister, S., Piccoli, E., Schaldach, R., Schüngel, J., Sonderegger, T., Sudheshwar, A., Tanikawa, H., van der Voet, E., Walker, C., West, J., Wang, Z., Zhu, B. A Report of the International Resource Panel. United Nations Environment Programme. Nairobi, Kenya.

Kirchherr, J. W., Hekkert, M. P., Bour, R., Huijbrechtse-Truijens, A., Kostense-Smit, E., & Muller, J. (2017). Breaking the barriers to the circular economy.

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). CE: the concept and its limitations. *Ecological economics*, *143*, 37-46.

Lanzi, E., Laubinger, F., and Chateau, J. (2020). Labour market consequences of a transition to a CE: A review paper. OECD Environment Working Papers, No. 162. OECD, Publishing, Paris.

McCarthy, A., R. Dellink and R. Bibas (2018). The Macroeconomics of the CE Transition: A Critical

Review of Modelling Approaches. OECD Environment Working Papers, No. 130. OECD Publishing, Paris.

OECD (2016), Extended Producer Responsibility: Updated Guidance for Efficient Waste Management, OECD Publishing, Paris.

OECD (2017), Tackling Environmental Problems with the Help of Behavioural Insights, OECD Publishing, Paris.

OECD (2019), Policy instruments for waste and materials management, in *Waste Management and the Circular Economy in Selected OECD Countries: Evidence from Environmental Performance Reviews*, OECD Publishing, Paris.

Preston, F., Lehne, J., & L. Wellesley. (2019). *An Inclusive Circular Economy Priorities for Developing Countries*. Chatham House Research Paper.

PricewaterhouseCoopers (2019). The road to circularity. Why a CE is becoming the new normal.

Raworth, K. (2017). *Doughnut economics: seven ways to think like a 21st-century economist*. Chelsea Green Publishing.

Rosenbloom, D., Markard, J., Geels, F. W., & Fuenfschilling, L. (2020). Opinion: Why carbon pricing is not sufficient to mitigate climate change—and how "sustainability transition policy" can help. *Proceedings of the National Academy of Sciences*, 117(16), 8664-8668. Chicago

Schröder, P., Anggraeni, K., & Weber, U. (2019). The relevance of circular economy practices to the sustainable development goals. *Journal of Industrial Ecology*, *23*(1), 77-95.

Schröder, P. (2020). *Promoting a Just Transition to an Inclusive Circular Economy*. Chatham House Research Paper.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223).

Stern, N. H., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., ... & Zenghelis, D. (2006). *Stern Review: The economics of climate change* (Vol. 30, p. 2006). Cambridge: Cambridge University Press.

Stiglitz, J. E., Stern, N., Duan, M., Edenhofer, O., Giraud, G., Heal, G. M., ... & Winkler, H. (2017). Report of the high-level commission on carbon prices.

Van den Berge, R. B. R., Magnier, L., & Mugge, R. (2020). Too good to go? Consumers' replacement behaviour and potential strategies for stimulating product retention. *Current opinion in psychology*.

White, K., Hardisty, D. J., & Habib, R. (2019). The elusive green consumer. *Harvard Business Review*, *11*, 124-133.

World Economic Forum (2014). Towards the CE: Accelerating the scale-up across global supply chains.

World Economic Forum (2020). As Canada bans bags and more, this is what's happening with single-use plastics around the world.

World Economic Forum (2021). Net-Zero Challenge: The supply chain opportunity. Insight Report, January 2021.

Contact

Johannes Buggle
HEC Lausanne & E4S
johannes.buggle(at)unil.ch

Jean-Pierre Danthine
EPFL & E4S
jean-pierre.danthine(at)epfl.ch

Paula Cacault
EPFL & E4S
paula.cacault(at)epfl.ch

About E4S

Enterprise for Society (E4S) is a joint venture of the University of Lausanne through HEC Lausanne, IMD and EPFL, under the stewardship of its College of Management of Technology, with the mission of spearheading the transition towards a more resilient, sustainable, and inclusive economy. E4S is dedicated to train the next generation of leaders, inspire economic and social transformation, and activate change by strengthening start-ups and boosting innovation.

Get in touch

info@e4s.center

https://e4s.center

https://www.linkedin.com/company/enterprise-for-society-e4s