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Transitioning to a sustainable circular economy: The transformation required to decouple growth from environmental degradation

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The UN 2030 agenda of Sustainable Development Goals (SDGs) envisions a future of inclusive equity, justice and prosperity within planetary boundaries, and places an important emphasis on *ending poverty* (SDG 1) and on *sustainable economic growth* (SDG 8). Target 8.4 refers to the need to improve global resource efficiency in consumption and production, and decoupling economic growth from environmental degradation, the ultimate goal of a sustainable circular economy. Here, we explore the potential of the transition to such an economy, and discuss the transformation required for moving away from our current model of consumption with its ever increasing generation of waste. The primary aim of such transformation is to rethink what we understand as growth, in order to redefine what is meant by progress and, in the process, redesign our economies, ultimately decoupling our prosperity from material consumption, carbon emissions and waste. Dematerialisation, servitisation, collaborative consumption and a shift from ownership to access have the potential to restructure the economics of consumption, accelerate decoupling, and help us to envision and potentially create a circular economy that delivers social, economic and environmental benefits for all. However, their current deployment without policy steer, public support and appropriate technology developments could turn to be a missed opportunity for ensuring sustainable economic growth fully aligned with sound environmental stewardship and social development, and the transition to a truly sustainable circular economy.

KEYWORDS

decoupling, growth, resources, materials, servitisation, efficiency, sustainability

Introduction

The world is facing global challenges and constraints due to resource depletion, wasteful and harmful production and consumption, and the emerging impacts of climate change. According to the UN (2021), extractive industries (mining and farming) contribute half of total global greenhouse gas emissions and over 90% of biodiversity loss, while the increasing material weight of the world's economies is imposing more dangerous levels of stress on climate and natural life-support systems than previously thought (Oberle et al., 2019). The toll on the environment was reflected in the joint climate and environment emergency declared by the UK parliament in May 2019

(UK Parliament, 2019), as well as the European Parliament in November the same year (European Parliament, 2019), recognizing the urgent need to reduce carbon emissions and address the over-consumption of the planet's limited resources.

The amount of materials consumed globally per year passed 100 billion tons in 2020 (Circularity Gap Reporting Initiative., 2020), composed of biomass (mostly food), metals, fossil fuels and minerals. From 43 billion tons in 1990, global material consumption rose to 54 billion tons in 2000 and 92 billion tons in 2017—an increase of 70% since 2000, and 113% since 1990. The rate has accelerated since 2000, and without decisive political action, it is projected to grow above 190 billion tons by 2060 (UN, 2021). This is the same level that humanity could have reached already in 2017, if everyone on the planet had the same per capita material footprint as those in high income countries (Figure 1), demonstrating how unsustainable our current model of development is.

Today, just over half of the world's population (4 billion people) live in households considered "middle class" or "rich," and this number will pass 5.3 billion by 2030 (HMG, 2021), when middle class spending is expected to grow to $64 trillion from about $37 trillion in 2017 (EUK4P, 2021). The consumption of this rapidly growing and increasingly affluent middle class is driving natural resource demand and consequent waste generation, further exacerbating unsustainable resource use and impacts. Based on current consumption patterns, demand for water, food and energy are expected, by 2030, to increase by approximately 40%, 35%, and 50% respectively compared to 2017 levels, along with increasing environmental degradation (Credit Suisse Research Institute., 2019).

In response to this increasing materially intensive resource consumption and its generation of large amounts of waste, *Resource/Waste Management* has developed over the last few decades to reduce the impacts of our consumption. However, its focus being on "end of pipe" solutions, waste management's success has been limited. For example, although waste recycling has become a core element of sustainable development, recycling in itself is insufficient to halt the depletion of natural resources, as their global consumption is faster than the rate they can be recovered through recycling or replenished by nature (Grosse and Mainguy, 2010). Material consumption has been increasing faster than increases in population, indicating that it is not driven by population growth but the current model of economic development based on consumerism and industrial mass production. Our myopic focus on producing and consuming as cheaply as possible has created a pervasive linear

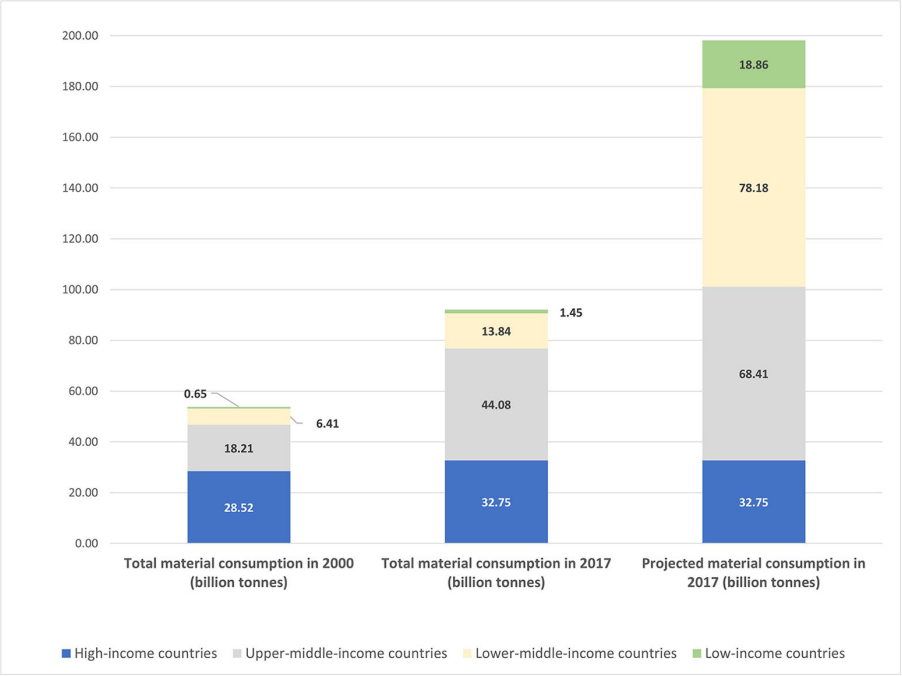

FIGURE 1
Total material consumption in 2000 (54 billion tons) and in 2017 (92 billion tons) with High-income, Low-income, Upper-middle-income and Lower-middle-income countries, with populations of 1.1 (1.3), 0.5 (0.7), 2.3 (2.6) and 2.3 (3) billion people, and total material consumption of 25.64 (26.27), 1.41 (2.02), 7.97 (16.93) and (2.81) 4.65 tons per capita in 2000 (2017), respectively (UN, 2021). If everyone in 2017 had the same footprint as the high income counties (26.27 tons per capita), total material consumption would be 192 billion tons.

economy in which objects are briefly used and then discarded as waste.

The UN 2030 agenda of Sustainable Development Goals (SDGs) envisions a future of inclusive equity, justice and prosperity within planetary boundaries, and places an important emphasis on ending poverty (SDG 1) and on sustainable economic growth (SDG 8). Target 8.4 refers to the need to "*improve global resource efficiency in consumption and production, and endeavor to decouple economic growth from environmental degradation in accordance with the 10-year framework of programs on sustainable consumption and production, with developed countries taking the lead*". Considering that the *Circular Economy* has in recent years "*gained increasing prominence as a tool for the transformation toward sustainable and resilient societies and holds particular promise for achieving multiple SDGs*" (UNDP Expert Group, 2018), here, we explore the potential of the transition to such an economy through improvements in resource efficiency and recycling, and discuss the transformation required for such transition to take place.

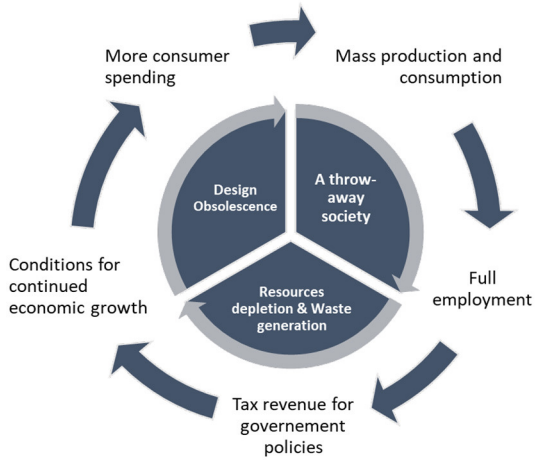

FIGURE 2
The current "take-make-waste" linear model driven by consumer spending.

The circular economy and decoupling growth from environmental degradation

The current model of development depends on the consumption of goods and services to drive economic growth, seen as the means for meeting society's needs (Mensah, 2019). It is an economic model of increasing production rates and use of natural resources to provide the raw materials to manufacture the goods needed to keep consumers spending. It is a virtuous economic circle embedded within the vicious circle of resource depletion, pollution, carbon emissions and waste generation (Figure 2), in the form of a linear economy based on mass production and consumption, designed obsolescence, and a throw-away society. This model of development is clearly unsustainable.

The challenge of meeting the needs of a growing world population with a finite resource base on a planet that is already under stress, comes down to an economy's ability to grow while resource use is declining, "*a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible*" (European Parliament, 2022), a concept widely referred to as the "*Circular Economy*." A systemic approach to economic development, the Circular Economy, has been increasingly gaining importance on the agendas of both business and government leaders inspired by its potential to decouple economic growth from virgin resource inputs and impacts, as the operational tool for sustainable development (Bassi et al., 2021). A transition to such an economy could increase economic growth, encourage innovation, and create more robust employment (Ellen Macarthur Foundation, 2017). Decoupling the economy from resource extraction and use and environmental degradation has therefore been increasingly regarded as an essential feature of a successful transition to a sustainable circular economy.

Defined as a decline in the environmental impact of every additional unit of economic output (UNEP, 2011), *decoupling* is one of the key principles of the *European Green Deal* (European Parliament, 2020) and underpins many aspects of the *Green New Deal* in the US (Ocasio-Cortez, 2019). It is also a foundational component of the UN 2030 agenda of Sustainable Development Goals, without which the goals themselves are unlikely to be achievable (Fletcher and Rammelt, 2017). Despite this, there are currently "*no credible, socially just and ecologically sustainable scenarios of continually growing incomes globally*" (Jackson, 2009), and no "*coordinated industrial strategy able to create sustainable wealth*" with continually declining material throughput has been put in place so far (Scheel et al., 2020). Decoupling might be widely recognized as the overarching goal of the circular economy, but has not been operationalised and rarely features as an integrated part of the transition process. In fact, it looks like we are expecting decoupling to emerge out of efficiency improvements or as a side effect of circular economy interventions designed without decoupling in mind.

Improved resource efficiency (Figure 3) is a necessary but not sufficient condition for decoupling since potential savings could be canceled out by increased production (Giljum et al., 2008; Huppes and Ishikawa, 2009; Wursthorn et al., 2011) and rebound effects (Jevons, 2001; York, 2006). For example, of the 27 EU Member States whose resource productivity improved between 2000 and 2017, several experienced substantial increases in demand for materials over the same period

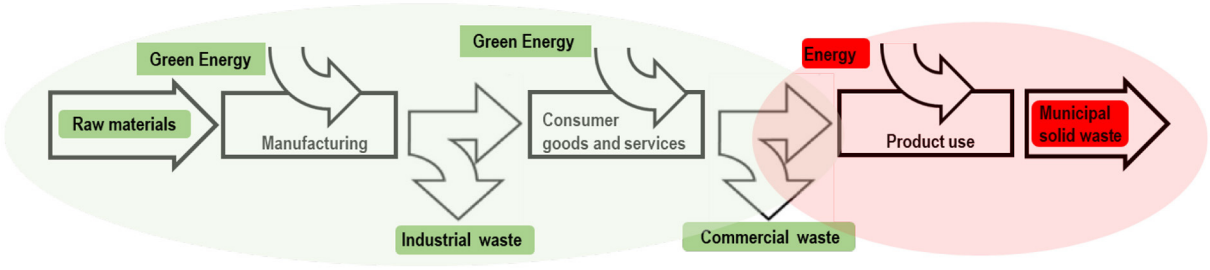

FIGURE 3
Reductions in materials, energy use and waste production per economic unit to reduce manufacturing costs, but also increases in overall production and post-consumer waste due to designed obsolesce and increases in demand.

(Malta 71%, Estonia 70%, Lithuania 63%, Bulgaria 46%, Luxembourg 34%, Poland 33%, Slovakia 32% and Sweden 31%) counterweighting any resource efficiency savings (EEA., 2018). Historically, the aim for producers has been to sell a maximum number of products at minimal cost, externalizing costs such as waste end manufacturing emissions till environmental regulations were introduced. While this worked well in the 20th century when resources were easily available and raw material prices kept decreasing, today the higher a company's rate of production and the higher its productivity, the greater its chances for maximizing revenue by selling more and more products, assuming there is a demand. And even demand can be "created," when manufacturers resort to practices that decrease the useful life of their products. "*Planned obsolescence*," intentionally reducing the life of goods, to generate long-term sales volume by reducing the time between repeat purchases (Bocken and Short, 2016), goes back to the 1930s and the essay by Bernard London titled: "*Ending the Depression Through Planned Obsolescence*" (London, 1932). When goods are thrown away before their useful life is over, precious natural resources are wasted, some of which cannot be renewed (DEFRA, 2018). The longer a product lasts, the greater the timescale and function over which the raw materials, manufacture, retail and distribution and end of life impacts are spread, and hence the less significant these impacts will be (DEFRA, 2011). *Obsolescence increases* consumption and post-consumer (municipal) waste as a result. It is a significant barrier to decoupling, and policies addressing it in the EU, have focused on Extended Producer Responsibility (EPR), which have seen producers rather pay a fee for a separate collection and recycling than actually reducing waste generation (Pouikli, 2020). So overall, despite improvements in resource efficiency, consumption has continued to rise.

Some relative decoupling has been taking place, as resources cost money that companies would rather not spend, so they invest in technologies that allow more output to be produced while spending less on material inputs. Between 2010 and 2018, in the EU, while total waste generation increased by 7% (50.3 million tons) mainly driven by economic growth, this increase was smaller than that of the economy, indicating some relative decoupling of waste generation (EEA, 2021). Still, there is no wide consensus that decoupling of waste is taking place (Madden et al., 2019), other than evidence of landfill diversion of waste as the result of EU policies (Nicolli et al., 2012).

In the absence of policies or interventions targeting decoupling directly, it is perhaps not surprising that we have so far failed to decouple economic growth from resource use, waste and carbon emissions, with any decoupling taking place "a*t a rate that is insufficient to meet the demands of an equitable and sustainable society*" (UNEP, 2011). For every 1% increase in global GDP, carbon emissions have risen by approximately 0.5% and resource intensity by 0.4% (GeSI, 2015). Current business practices will contribute to a global gap of 8 billion tons between the supply of and demand for natural resources by 2030, translating to a potential $4.5 trillion loss of economic growth (Lacy and Rutqvist, 2016), if the demand is not met.

Most of the focus of current circular economy initiatives has been on recycling and recovering materials from waste, what is termed as "closing the loop" (Figure 4). However, recycling in itself is insufficient to perform the "decoupling" required, as it does not tackle waste generation or result in waste prevention, and while recycling rates have been tremendously increased in several countries, the potential of recovering value and reducing demand on virgin resources has been limited by several factors (i.e., recycling also consumes energy and resources, is subject to laws of thermodynamics and is not economically viable for all waste streams). Ambitious EU targets introduced in 1994 and 2008 and later by the circular economy packages (2015), focusing more on collection for recycling rather than value recovery, also limited recycling's decoupling potential, increasing plastic waste exports for processing abroad (Antonopoulos et al., 2021). In general, once products are discarded and enter the waste stream, their potential for repair, reuse or recovering value reduces significantly.

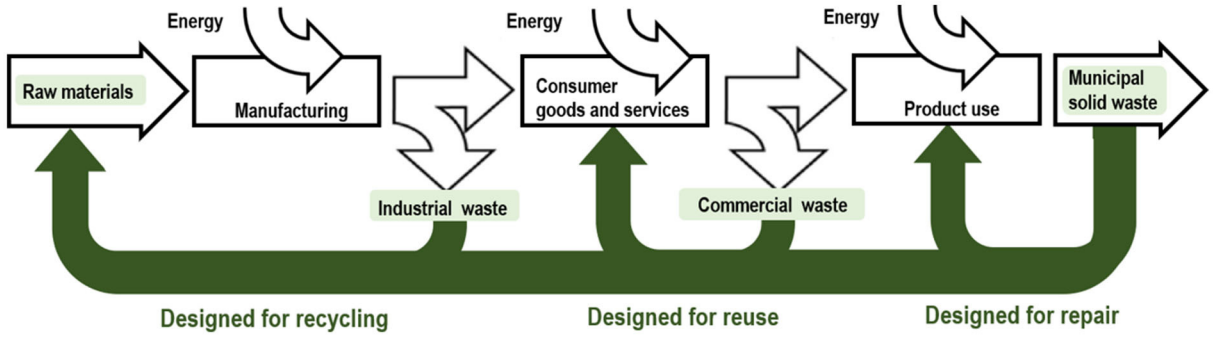

FIGURE 4
Closing the loop, as a way of reusing products and recovering materials that are destined for disposal.

It is therefore increasingly becoming clear that just "using fewer resources and reusing and recovering products and materials that are destined for disposal" is not an effective strategy for a sustainable growth model. In fact, for decoupling our current linear consumption, waste prevention policies would need to be in place to deliver a decrease of consumption and, in further consequence, a decrease in manufacture, extraction and processing and use of primary resources. Such policies would be in conflict with current economic drivers, and would be heavily opposed by businesses for potentially reducing their profits. Within our current model of development, they could also result (or be perceived to result) in lowering people's standards of living, making their life experience less rich so as to lessen their individual claims on limited resources.

The circular economy therefore needs to go beyond recycling and resource and energy efficiency; it needs to keep products in the economy, by reusing them, repairing or upgrading them, then doing the same with product components and parts and only as a last resort having materials recycled, with manufacturers ultimately extending value throughout the life cycles of their products. But more importantly, the transition to a sustainable circular economy requires us to rethink what we understand as growth, in order to redefine what is meant by progress and, in the process, redesign our economies, gradually decoupling our prosperity from material consumption and waste.

There is now an urgent need for a range of technological, institutional and behavioral changes which are justified and driven by the decoupling agenda. Notably, dematerialisation, servitisation, collaborative consumption and a shift from ownership to access are all likely to be essential to accelerate the decoupling needed to transition to a sustainable circular economy (DEFRA, 2018). Servitisation, for instance, takes place when traditional product-based firms move toward service-based business models that focus on selling the solutions that the products can deliver, rather than selling products *per se*. Switching the base of the transaction toward access and performance has the potential to restructure the economics of consumption, encouraging more sustainable use of resources and delivering wider benefits to human health and well-being (Bellos and Ferguson, 2017).

Servitisation and the circular economy

The United Nations Environment Programme sees *servitisation* as having "*the potential to re-orient the current standards of consumption and production, thus enabling a move toward a more sustainable society*" (Manzini and Vezzoli, 2002). Similarly, the EU defined servitisation in its 2000 Growth Programme as "*ways to fulfill functions and provide services to end users without necessarily transferring the ownership of the product to them*" (European Commission, 2000). The concept was moreover supported by the 2011 European Commission Communication, "*The Roadmap to a Resource Efficient Europe*" (European Commission, 2011), which outlined how Europe's economy can be transformed into a sustainable one by 2050, and later was a key component of the *Circular Economy Action Plan* adopted in 2020-one of the main blocks of the *European Green Deal*, "Europe's new agenda for sustainable growth" (European Commission, 2020).

Moving from a product to a service-based economy offers a potential pathway for the transition to a sustainable circular economy, and a system state where decoupling of economic growth from resources and pollution can emerge. In such an economy (also termed as *performance economy)*, the economic activity is not the sale of the product but the performance (the function) the product provides, and the benefits offered to the user. The "service economy" therefore refers not to the tertiary sector, but to an "*economy where value is created by services and the majority of jobs are in service activities*" (Bardhi and Eckhardt, 2012; Smith, 2016). This is captured well by Theodore

Levitt's quote that "*People don't want to buy a quarter-inch drill. They want a quarter-inch hole!*". The sharing economy, similarly, refers to peer-to-peer based sharing of access to goods and services often facilitated by a community-based online platform, focusing on the sharing of underutilized assets in ways which improve efficiency, sustainability and community (Heinrichs, 2013).

Servitisation, sharing and leasing could make a significant contribution to sustainable economic growth, shifting the paradigm from ownership to access and to functions that deliver benefits to users. Reduced demand for consumer goods will impact pollution and excessive resource use directly (Prothero et al., 2011; Milanova and Maas, 2017), while allowing improvement of standard of living and overall wellbeing (Bonciu and Balgar, 2016). By focusing on the service rather than the product, systems with significantly lower impacts become much easier to design (Tukker, 2015) as firms have an incentive to prolong the service life of products to ensure they are used as intensively and for as long as possible (Stahel, 1986; Tietze and Hansen, 2016), to maximize profits from their use (Probst et al., 2016), resulting in resource savings. Service based systems where ownership stays with manufacturers, for example, can offer better capture of end-of-use products; improved access and replaceability of main components; and end-of-life refurbishment. Products need to be redesigned and manufactured durable in order to last while they are being leased, rented, or shared, with their ownership remaining with the manufacturers, so that at the end of their useful life can be returned in order to be fixed, remanufactured or recycled (European Commission, 2014).

In a service economy, consumers have an economic incentive to use products efficiently and manufacturers have an opportunity to increase consumers' interests in environmental issues (Manzini and Vezzoli, 2003). Servitisation requirements such as product design that extends their lifespans, improved repairability, upgrading potential, parts availability, standardization and improved consumer information can deliver significant sustainability benefits, while making the need for product obsolescence redundant (Prakash et al., 2020). Moreover, they offer an incentive for manufacturers not only to produce durable goods but ones that can be easily upgraded, repaired, reassembled or remanufactured (when end-of-life goods can be restored to their original working condition). Policies and initiatives at the European and global level have emphasized the potential of remanufacturing in facilitating the transition to the circular economy, useful in extending the lifespan of products and preserving value in the economy. Several studies demonstrate how servitisation can improve perceived value and reduce the perceived risk of remanufactured goods, a promising strategy for increasing their purchasing (Tondolo et al., 2021).

Emerging business models–some of them adopted by multinational corporations –promote circular economy practices, focusing on services (e.g., mobility, music or cleaning) rather than product sales (e.g., cars, CDs or washing machines). In industry in particular, manufacturers have been doing this by extending into more "advanced" services. *Rolls-Royce*' *TotalCare* service to airline and cargo carriers keeps the ownership of a plane's engines and therefore the burden of their maintenance with Rolls-Royce. The cost to airlines for operating and maintaining their fleet engines is fixed through a dollar-per-flying-hour payment mechanism. This model offers great opportunities and benefits to both sides, maximum flying availability, route optimisation and end-of-life management. Developments in digital technology mean that Rolls-Royce can also gather large amounts of data on performance, enabling them to plan maintenance or repair activities proactively, minimizing disruption and optimizing resource efficiency by keeping engines flying for longer, reducing demand for new parts and components that are expensive and resource intensive to manufacture. Up to 95% of a used aero engine can be recovered and recycled, made easy when its ownership stays with the company. Increases in service intervals between engine overhauls by around 25% have also been reported with this model (Rolls Royce TotalCare, nd). Other examples include *TrainLife Services* offered by Alstom, providing trains with a bundle of repair and maintenance services charged on a miles traveled basis through 15–20 year contracts; Xerox's Print Management system offering copiers as a service charged on the number of pages copied or printed; M-Use®: an elevator leasing service offered by Mitsubishi; and MAN's trucks pay-per-kilometer programme charged by the distance trucks are driven.

To assess the environmental implications of servitisation, life cycle assessments -which estimate environmental impacts associated with all the stages of a service provided, have been more widely applied to businesses (Martin et al., 2021) compared to servitisation of consumer products. In fact, a large body of literature shows servitisation in industry delivering improved environmental performance (Annarelli et al., 2016). For example, three showcases in a study by Lindahl et al. (2014), demonstrated that servitisation systems can significantly lower environmental impacts (up to a factor of 10) and increase economic benefits compared to conventional purchase systems.

In the case of consumer goods, servitisation would require the manufacture of fewer but durable, repairable and upgradable high-quality products, in contrast to the excess of cheap disposable goods that flood consumer markets today. For example, using domestic appliances for as long as possible has been shown to be beneficial both for consumers and the environment. The argument that improvements in the environmental performance of new products justify the replacing of older ones only works if those improvements outweigh the environmental costs associated with both their manufacturing and the disposal of the ones being replaced. In the case of domestic appliances such as washing machines,

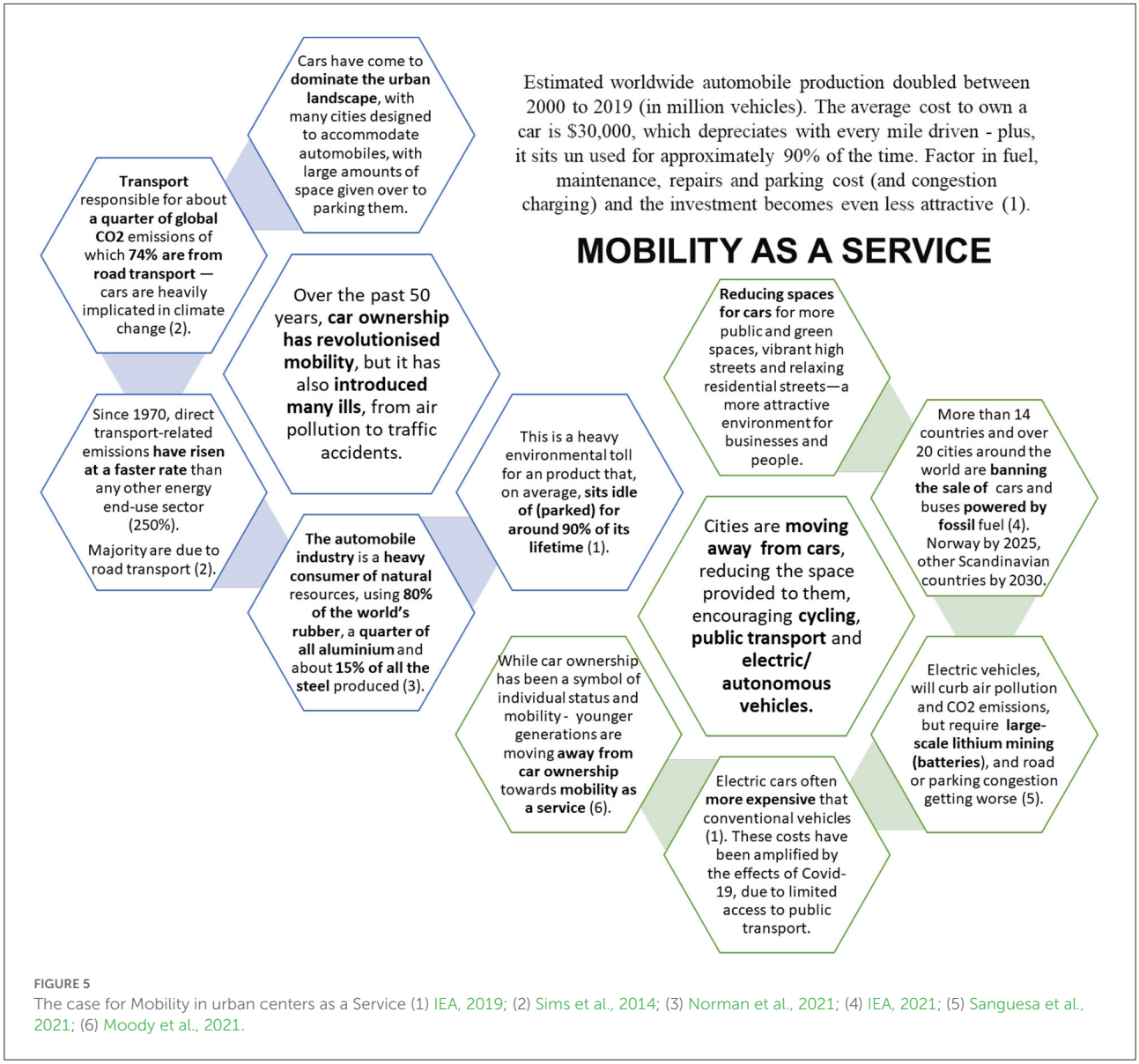

FIGURE 5
The case for Mobility in urban centers as a Service (1) IEA, 2019; (2) Sims et al., 2014; (3) Norman et al., 2021; (4) IEA, 2021; (5) Sanguesa et al., 2021; (6) Moody et al., 2021.

dishwashers, dryers and refrigeration products, this would only be the case with old dryers and fridges, as recent advances in technology (e.g., heat pump systems) have led to substantial improvements in efficiency (Oeko-Institut, 2014). A transition from consumers as buyers to users of washing machines would result in reductions in both material and energy use, and savings for both consumers and manufacturers. A high-quality washing machine with a life span of 20 years, when leased for 5 years instead of being sold, could be refurbished between users. "*Given similar material compositions and production processes, replacing five 2,000 cycle machines with one 10,000 cycle machine yields almost 180 kg of steel savings and more than 2.5 tons of CO_2e savings*" (Fletcher and Rammelt, 2017). Another promising application of servitisation to sustainability is *transport and mobility in urban centers as a service* (Figure 5).

The market for maintenance, repair and operations of consumer goods in he EU is expected to grow to around EUR 33 billion by 2025, with margins on services on average 10.7% higher than on products (Oeko-Institut, 2014). In the UK, WRAP estimated that GVA could have increased by £75 billion by 2030, if a widespread roll-out of resource efficient business models across the UK economy had taken place (REBus, 2017). Such business models could have also accrued multiple additional social, economic and environmental benefits, not least, protecting national resource security in turbulent political times. In fact, closing the loop on resource use and moving to a service-based economy has the potential to boost the UK

economy by 1.8% over a 10-year period, potentially adding a total of £29 billion to GDP, as well as creating new jobs and significantly reducing the country's environmental impact (Voulvoulis, 2015).

The need for sustainability transformation

Many technology and manufacturing companies have already adapted business models offering services than selling products, as a way of improving competitiveness and responding to customers' needs (Tuli et al., 2007). Artificial Intelligence, the Internet of Things and sensor technology have led many manufacturers to redefine the ways they do business (Microsoft., 2018), reflecting emerging trends in consumer preferences from "ownership" to "access," driving businesses to new revenue streams (PWC, 2014). However, successes in transitions to servitisation so far have been varied and even in the best cases, limited to securing stable revenues and generating higher profits, but not delivering significant sustainability improvements (O'Rourke and Lollo, 2015).

As they are being developed currently, the *services*, *lease* and *sharing* economies are not per se environmentally sustainable and have not yet resulted in tangible large-scale reductions in environmental impact (Curtis and Lehner, 2019). Research shows that many existing business models that are premised on delivering services than selling products have not been designed with sustainability in mind, and therefore do not deliver the environmental improvements expected with servitisation (Corvellec and Stål, 2017). Service offerings can still require consumption of natural resources and make waste inevitable. Fundamental changes to institutions, decision making structures and human behavior as well as a rebalancing of socio-economic systems are required (Knight et al., 2013). The difference is in the opportunities for collection/return and repair, remanufacture and recycling systems offered by servitisation, products' durability and longer lifetime servitisation requirements, and more efficient use of our stock of natural resources for products that are shared or stay in the economy longer, and can be fixed, upgraded, and reused. The evidence for a link between environmental motivation and participation in the current service/sharing offerings is also weak. There are moreover several social concerns with some of the practices related to sharing/ service business models (Bogliacino et al., 2019). For instance, the Uber economy is considered to be unstable, "*based on a growing 'army' of freelancers and part-timers*" (Codagnone et al., 2016). Similarly, 'sharing' consumer goods can actually decrease their useful life, if those goods have not been designed for sharing or servitisation. Without policy steer, consumer support, access to tools for long term planning and business decision making, and investments in sustainable product redesign, servitisation and sharing models do not automatically result in environmental wins.

Servitisation and decoupling pathways offer leverage for sustainability transformation that can provide an incentive for businesses to increase durability of products, change their business models and redesign their offerings. This fundamental shift has the potential to reduce the environmental impacts of our current linear unsustainable economic system (Plepys et al., 2015). Such pathways, however, will require a fusion of technologies and new infrastructure, supported by research activities that aim to shift the deeper structures of consumption toward sustainable commons and user access. The key outcome will be the decoupling of economic activity from natural resources, in this case, through dematerialised services provision and symbiotic relationships, building on and complementing initiatives that up until now mainly focused on recovering value from waste.

It is a challenging transition that needs co-ordinated policy support to succeed. For example, legislative drivers such as waste prevention targets and eco-design incentives can promote better product design, as well as product stewardship by manufacturers across the life cycle of their goods (Probst et al., 2016). Both economic and noneconomic incentives can encourage the use of products and services with a proven and certified positive impact on the environment, demonstrated for example by passing complete standardized Life Cycle Assessments (Mi and Coffman, 2019). This can also impact consumers' perceptions and lack of awareness relating to new and untested eco-friendly alternatives (Probst et al., 2016). Additionally, there is a need to make funding available to entrepreneurs and to those companies adopting pay-per-use schemes, to cover some of the large upfront capital investments required for redesigning or purchasing products that meet the servitisation requirements. Coupling financial assistance to sustainability requirements can both inform and direct companies toward green growth.

The concept of a circular economy is the result of moving from a simple, impact-reduction model to one of absolute value creation that delivers social, economic and environmental benefits. Part of a future of inclusive equity, justice and prosperity within environmental limits inspired by the SDGs, it is about development and prosperity decoupled from resource use, waste generation and carbon emissions. Making the transition to such an economy is an important goal for society and individual companies, particularly in resource-intensive manufacturing industries. Yet, "*the complexity and interdependencies of such an undertaking mean that no single company can achieve this alone and ecosystem-wide orchestration is necessary*" (Parida et al., 2019). We need a coordinated, holistic, integrated and interdisciplinary systems approach based on wide public participation and engagement. The vision of a sustainable circular economy, as a collective goal desirable to everyone, can provide the basis for engaging the participation of diverse stakeholders in the process of

making such a vision realize through appropriate interventions and policies.

Discussion

Unsustainable resource extraction and use, overconsumption, and waste are typical of a throw-away society, with products discarded as waste within absurdly short timespans and new consumer goods being produced and purchased by the millions every day. Consumption has reached an all-time high and sits at the heart of many of our most critical environmental, social and health problems, "*deeply ingrained in behaviors, cultures, and institutions, and...driven and supported by corporate and government practices*" (O'Rourke and Lollo, 2015). *Product obsolescence*, be it technological, designed, psychological or economic, has actually resulted in a decrease in the first useful service life of most of consumer goods over recent years (Prakash et al., 2020). Having developed in many subtle and complex ways, *obsolescence* makes the coupling between economic growth and materials even stronger. There have been several documented cases of goods designed to make repair unviable, such as non-removable batteries in mobile phones, sealed drums in washing machines, and inkjet cartridges with a chip to stop them being refilled (Aladeojebi, 2013). In 2020, French regulators fined Apple €25 million ($27.4 million) over a software update in 2017 that slowed down older iPhones, the highest fine for fraud ever imposed by the French consumer watchdog. Obsolescence undermines consumer choice and increases costs of owning and using products, accelerating the destruction of useful objects and resulting in higher levels of resource extraction and waste produced (Green Alliance., 2015).

According to DEFRA (2018), "*evidence suggests that 80% of the damage inflicted upon the environment when products become waste can be avoided if more thoughtful decisions – about product design, the choice of materials and chemicals used, and how they will be distributed and sold to consumers – are made at the production stage*". Still, historically, the political response to addressing waste challenges both in the UK and the European Union has focused on post-consumer waste, following the waste hierarchy, diverting waste from disposal to landfill, increasing recycling and energy from waste. Much less effort has been put into how we design, make and deploy products, and prevention of waste throughout the product life cycle, areas where policy intervention could have a much greater chance to deliver improvements in both how we manage our stock of natural resources and the amounts and types of wastes we generate.

Now, heightened public awareness of the growing and unsustainable demand for resources and production of wastes and concerns about emerging resource security issues, carbon emissions and climate change provide policy makers with a unique mandate for change and businesses with the opportunity to see the purpose of their systems for production and consumption redefined to ensure sustainability. Some experts have argued that everyone (or at least those who can afford it) has a responsibility for example "*to reduce carbon emissions and limit climate change, even if each individual action is insufficient in itself to make a difference*" (Byskov, 2019). Yet, the problems we are facing are at a planetary-scale and cannot be solved by small incremental actions. They require systemic changes, planetary-scale reforms that can only be implemented by the world's governments, as well as businesses and corporations.

Transformations to sustainability involve fundamental redirections of current human-environmental interactions (Shrivastava et al., 2020), requiring coordinated policy, technology, behavior and market interventions (Voulvoulis et al., 2022). Instead of smaller incremental adaptations in technology, lifestyles or governance arrangements, we need to develop tools that allow us to plan effectively large-scale social, political and behavioral change, generating options for deliberate transformations that will address the social logic of consumerism-dismantling the perverse incentives for unproductive status competition and offering new structures to encourage prosperity (Curtis and Lehner, 2019). It is about the radical transformation of the way the world uses natural resources, the type of transformation that is central to also achieving the SDGs, reaching the Paris Agreement and Net Zero greenhouse gas (GHG) emission targets.

Reaching Net-Zero before 2050 for example, requires extensive changes across the economy, and reducing energy-related carbon through energy efficiency and renewable energy alone is not enough. The circular economy can play a key role in delivering Net Zero targets. While resource efficiency and "closing the loop" can contribute to decarbonisation, it is decoupling as discussed earlier that has the greatest potential. It might be tempting to focus more on carbon emissions, and even rely on Carbon Capture and Storage ("CCS") as one of the ways to reach net zero, but such an approach could be "*an expensive distraction to a circular economy*" (Zero Waste Europe., 2021). In particular, the debate should not just be about the role of CCS but ways in which the transition to a circular economy can deliver decoupling and therefore reduction in emissions. The profusion of net zero targets from countries, cities and businesses is distracting from the sustainability transformation needed, targeting the symptoms rather than the causes of climate change.

More importantly, we need to step back and see the bigger picture, and as a society put forward an aspirational view of a sustainable future, a vision for the circular economy we want to transition to. Empowering citizens to envision a sustainable, poverty, inequality and injustice-free future that is both possible and desirable and that can be delivered through sweeping environmental and economic reforms, seems to be the most effective approach for the transformation required.

Such vision can guide, motivate action, and inspire people and systems to change (Meadows et al., 1992), as well as enable us to identify the interventions needed for the vision to realize. It also needs leveraging by behavior change dynamics and grassroots community involvement toward resilient and inclusive decoupling pathways.

It comes down to answering the question of how to serve the rapidly expanding global population with its rising standards of living, through offerings that satisfy individual needs and wants decoupled from natural resources, carbon emissions and waste. Such decoupling will need new policy instruments, investment in new technologies and development of decision making tools that prioritize sustainability. It will also need public engagement to empower consumers; consumers are considered to be empowered if they are "*offered sustainable choice options for their everyday necessities which are easy to identify, trust, and understand, and which fit into their current way of life without making unreasonable demands on time, effort (including decision-making effort), and money*" (Lang et al., 2012). Businesses therefore have a key role to play. Research and innovation are needed to enable governments and businesses to address the needs of the rapidly expanding global middle class, impelled by the emerging world view that sustainable economic growth needs to be fully aligned with sound environmental stewardship and social development. This can only be economic growth that aims to satisfy the needs of all humans in a manner that sustains natural resources and protects the environment for future generations.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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