Innovative approaches to peace and security from the Stanley Foundation

POLICYANALYSISBRIEF

THE STANLEY FOUNDATION | MARCH 2018

# Looking Beyond Borders
## The Circular Economy Pathway for Pursuing 1.5° C


## Summary

Global greenhouse gas (GHG) emissions continue to increase, and bringing them back onto a 1.5° C emissions pathway is increasingly challenging as the remaining carbon budget is rapidly depleted.[1] Most current approaches to identifying mitigation opportunities, climate policies, international cooperation, and capacity building target the source of emissions. This has been instrumental in reducing emissions in the short run, but for deeper reductions, the focus must shift to the root causes of GHG emissions, moving from incremental improvements to transformational change.

Sixty-seven percent of global emissions are related to material management and the excessive use of primary resources, such as minerals extracted from the earth. Most current economic models are predominantly linear. They extract material, utilize it, and then dispose of it. Circular economy models minimize the harmful extraction of resources from the lithosphere and avoid waste disposal. They do so by optimizing the use of existing materials and assets that have accumulated since the Industrial Revolution and by focusing on regenerative sources of materials and energy. Considering the large share of GHG emissions associated with material management, circular economy strategies can deliver emission reductions beyond incremental changes by targeting the cause of emissions rather than simply the source of emissions.

Developing countries have a major opportunity to leapfrog toward societal models that are both circular and carbon neutral by design. Developing and emerging economies are currently creating the infrastructure and buildings to provide shelter, mobility, nutrition, communication, and a range of other services to current and future generations. These assets represent large material stocks that drive GHG emissions during their own production, manufacturing, and assembly, but also lock in the carbon footprint of societies during their service life. In the case of buildings and transport infrastructure, this service life typically extends for several decades.

International cooperation on climate change mitigation and national climate policies do not yet leverage circular economy strategies to their full potential. Under the Paris Agreement, there is an opportunity to raise the climate



Jelmer Hoogzaad

Matthieu Bardout

Jelmer Hoogzaad is a senior circular economy and climate change mitigation adviser at Shifting Paradigms. He uses metabolic approaches to identify circular economy mitigation opportunities and advocates for the adoption of metabolic analysis and circular economy strategies to raise mitigation ambition under the Paris Agreement.

Matthieu Bardout leads Circle Economy's climate change work, focusing on practical and scalable adoption of circular economy strategies to mitigate climate change. He was formerly a consultant on climate finance and policy and has a robust understanding of the transformational change needed to deliver on the Paris Agreement.

policy ambitions that countries expressed in their nationally determined contributions (NDCs) and use the mechanisms within the agreement to facilitate international cooperation along global supply chains. By mapping material and energy flows and developing an understanding of how these flows help meet societal needs—a process called metabolic analysis[2]—countries can identify additional circular mitigation opportunities. A metabolic analysis also helps identify opportunities to reduce GHG emissions that cut across sectors and national borders.[3]

Metabolic analysis should be a cornerstone of capacity building at the national level and help countries create integrated development perspectives that enable them to advance on a broad set of sustainable development indicators.[4] Governments should also be incentivized to take domestic action, particularly where they are well positioned to reduce emissions in other countries through higher levels of relevant value chains. This can be achieved by complementing the current climate toolbox to enhance transparency on emissions and policy ambition, with consumption-based accounting for national emissions.[5]

At the national policy level, tax reform is needed that goes beyond the taxation of GHG emissions and abolishment of fossil fuel subsidies. Reforms should aim to reduce the tax burden on labor while increasing public revenues from levies on resource and energy use and waste disposal. This would make it more cost effective to repair something that would otherwise just be discarded and replaced with a new product. Incentivizing the private sector to consider end-of-life product stages, integrating this into the design of the product, can have major impact. Examples of policies that can have this effect include the European Union's (EU) Ecodesign Directive—which aims to make products circular and low-carbon designed—and the French experience with extended producer responsibility (EPR).[6]

At a business level there is untapped potential to develop circular economy investment opportunities with high mitigation potential. Where most climate policies and projects target the supply side and efficient production of material products, circular economy strategies add a demand-side aspect. In addition to altering demand, circular economy strategies can help optimize material selection and use in order to reduce GHG emissions. For example, the substitution of carbon-intensive materials for low-carbon materials, or even materials that create a net sequestration effect, offer significant GHG reductions when used in long-term applications like buildings and infrastructure. Similar opportunities exist for organic materials that offer mitigation through the closure of nutrient cycles.

There is a need to build an international forum of governments, non-state actors, and academia intent on closing material cycles and obtaining value from the materials and products that already exist. This coalition would consist of frontrunners that do not shy away from the systemic changes that are required and that understand the merits of addressing excessive resource use and GHG emissions in parallel. This policy analysis brief suggests policy opportunities at the national and international levels on climate action. It includes tangible examples of projects that can deliver on the promise of a circular economy and provides suggestions to use climate finance in a way that not only reduces GHG emissions but also avoids locking in a linear future.

This brief begins with a description of global materials flows, including fossil fuels, and how a linear process of material extraction, use, and disposal drives GHG emissions. It then describes how current assets, or stocks, like the buildings and infrastructure that provide shelter and mobility, lock in future GHG emissions. Thereafter, it introduces several examples of circular economy policies and technologies with a high mitigation potential and shows the small extent to which these are considered in climate policy or international cooperation under the Paris Agreement. Tapping into this potential requires that circular economy concepts become an integral part of national policies, international cooperation, and metrics under the Paris Agreement. This opportunity is substantiated in a series of recommendations for national policies and action under the architecture of the Paris Agreement.

*Keeping global warming within the targets of the Paris Agreement requires mobilizing the mutually reinforcing combination of low-carbon development and the efficient use of the material resources and assets that already exist.*

## Introduction

According to the latest United Nations Environment Programme's (UNEP) Emissions Gap Report, the full implementation of all climate policy pledges submitted under the Paris Agreement would still deplete the remaining carbon budget for limiting global warming to below 2.0° C by about 80 percent by 2030. The report identified six main mitigation options that can reduce GHG emissions by 22 billion tonnes of carbon dioxide equivalent per year (GtCO2e/year) at a price below $100 per tonne of carbon dioxide equivalent (tCO2e): solar energy, wind energy, efficient appliances, efficient passenger cars, afforestation, and stopping deforestation.[7]

*Globally, only 9.1 percent of materials in use by society are secondary materials; the remaining 90 percent are lost.*

Limiting global warming to 1.5° C by 2100 requires realizing an additional 19 GtCO2e of emissions reductions, beyond the current set of climate policies and strategies.[8] Keeping global warming within the targets of the Paris Agreement requires mobilizing the mutually reinforcing combination of low-carbon development and the efficient use of the material resources and assets that already exist. Circular economy strategies and analytics can deliver exactly that.[9]

A transition to a circular economy requires changing the way economic systems create value and respond to the needs, and perhaps desires, of society. It calls for transformational change that is deeper, but not less fundamental, than the shift from fossil fuels to renewable energy. Tapping into renewable energy sources and improving energy efficiency reduces reliance on fossil fuels, but in some cases the question is actually whether certain applications warrant the use of valuable energy at all. A transition to a circular economy requires asking exactly these questions, not just for energy but for materials use too.

Contrary to an economy where value creation is based on turning natural resources into products or assets, a circular economy is focused on more effectively responding to the fundamental needs of society. In line with the Sustainable Development Goals (see box 1), a circular economy also caters to the reduction of GHG emissions and the creation of decent jobs.[10] It fosters responsible consumption and production and the development of a clean living environment, and it promotes equality, since inequality is closely connected to unequal access to resources.[11]

### Box 1: Circular Economy and the Sustainable Development Goals

The vision of a circular economy eliminates the main characteristics of a linear economy: waste disposal and the excessive extraction of primary resources. Waste production and disposal, GHG emissions, unequal access to resources, and large-scale resource extraction are all activities that aggravate many of the issues that the Sustainable Development Goals (SDGs) aim to address. While transition to a circular economy cannot guarantee progress on all SDGs, its transformational ambition and focus on the root causes of issues the SDGs aim to address is an unprecedented opportunity to inspire positive change on a range of environmental and socioeconomic indicators in all countries.

The SDGs and the underlying indicators[12] require eliminating waste (SDG 12.5) and the GHG emissions that drive climate change (SDG 13.2), avoiding food waste (SDG 12.3), the degradation of water quality due to pollution and the management of water resources (SDGs 6.3-4-5, 14.1-3), and deaths and fertility issues from exposure to hazardous emissions (SDGs 3.9, 12.4) in rural and urban areas (SDGs11.5, 11.6). In a circular world, natural resources must be managed better (SDG 12.2), companies should be encouraged to report on sustainability (SDG 12.6), green public procurement should be incentivized (SDG 12.7), people should be informed on the lifestyles that are harmonious with nature (SDG 12.8), and developing countries should be supported in strengthening their scientific and technological capacity to move toward more-sustainable patterns of consumption and production (SDG 12.A).

In a circular world, there is no room for excessive extraction (SDGs 15.1-2, 14.4-6, 15.7), and the soil degradation (SDG 15.3), nutrient dissipation (SDG 14.1), and overuse of fertilizers and pesticides, which diminish the diversity of species and disrupt ecosystems that provide food (SDGs 2, 15.4-5), are eliminated.

Finally, in a circular world, developing countries continue to build their economies (SDGs 8.1, 9.2), infrastructure (SDGs 9.1, 9,4, 9.A, 11.2), and housing (SDG 11.1); people have decent jobs (SDG 8.5); and developed countries take the lead on improving global resource efficiency in consumption and production (SDGs 8.4, 12.1). One of the core principles to achieve this is to encourage collaboration (SDG 17). Examples are collaboration along international value chains, in standard setting on material selection and circular product design, between consumers in the sharing economy, and between producers and consumers in new business and service models.

# Resource Flows and Stocks

## Excessive Resource Extraction Feeding a Linear Economy

In a linear economic system, materials and products are extracted, used, and then disposed of. Globally, only 9.1 percent of materials in use by society are secondary materials; the remaining 90 percent are lost.[13] To feed the predominantly linear global economy, 84 billion tonnes of resources were extracted in 2015, excluding water. From 1970 to 2010, global material extraction tripled,[14] and population and economic growth are expected to push the amount of resources extracted to 186 billion tonnes per year by 2050.[15] Such growth would come with gross environmental consequences like climate change, biodiversity loss, ocean acidification, disrupted nitrogen and phosphorous cycles, soil degradation, and freshwater overexploitation.

About half of the materials in use—fossil fuels, food, fodder, and fuel wood—provide energy and nutrition. The other half—metals, minerals, timber, asphalt, and plastics—are used in long-term applications, to build up, maintain, and replenish physical stocks and assets. These stocks are the buildings, infrastructure, and consumer products that provide shelter, mobility, communication, and other valuable services to society. The stocks are where material use is very different from fossil fuel use. Materials can be cycled and provide services as products. Most fossil fuels are combusted and turned into harmful greenhouse gasses soon after their extraction.

From 1900 to 2010, global material stocks increased 23-fold, reaching 792 billion tonnes in 2010. Most of the stocks in use today are relatively new, with 82 percent of current stocks less than 30 years old. Yet these stocks are continuously being replenished or destroyed, and forecasts indicate that an estimated 25 percent of all stocks in use in 2010 will have been discarded by 2030.[16]

In some developed countries, stock levels have stabilized, and in some cases they have even started to decrease. Developing and emerging economies, however, are rapidly building up their stocks. For example, China's share of global stocks has more than doubled from 10 percent to 22 percent since 1990, and the country's net additions to stock have surpassed those of industrial economies.[17]

## Meeting the Needs and Desires of Societies

To identify ways to reduce the global material footprint, it is necessary to understand how the 84 billion tonnes of materials extracted annually are used. Figure 1 depicts an analysis of the global metabolism, which is the flows of materials in the global economy and how different types of raw materials, including fuels, are used to respond to the needs and desires of society. It also shows that only an estimated 8.4 billion tonnes of materials are recovered and reused as secondary materials each year. Based on this, it is estimated that the world is only 9.1 percent circular.[18]

These resources are used to respond to the needs of society. The three societal needs that require the most materials are housing and infrastructure, nutrition, and mobility.

Housing and infrastructure, or the construction sector, uses close to half of all global resources, which are primarily minerals (the sand, gravel, and limestone in concrete production), steel, and wood. These construction materials are mostly locked into material stocks over a long period of time.[19] This is a resource flow that is particularly

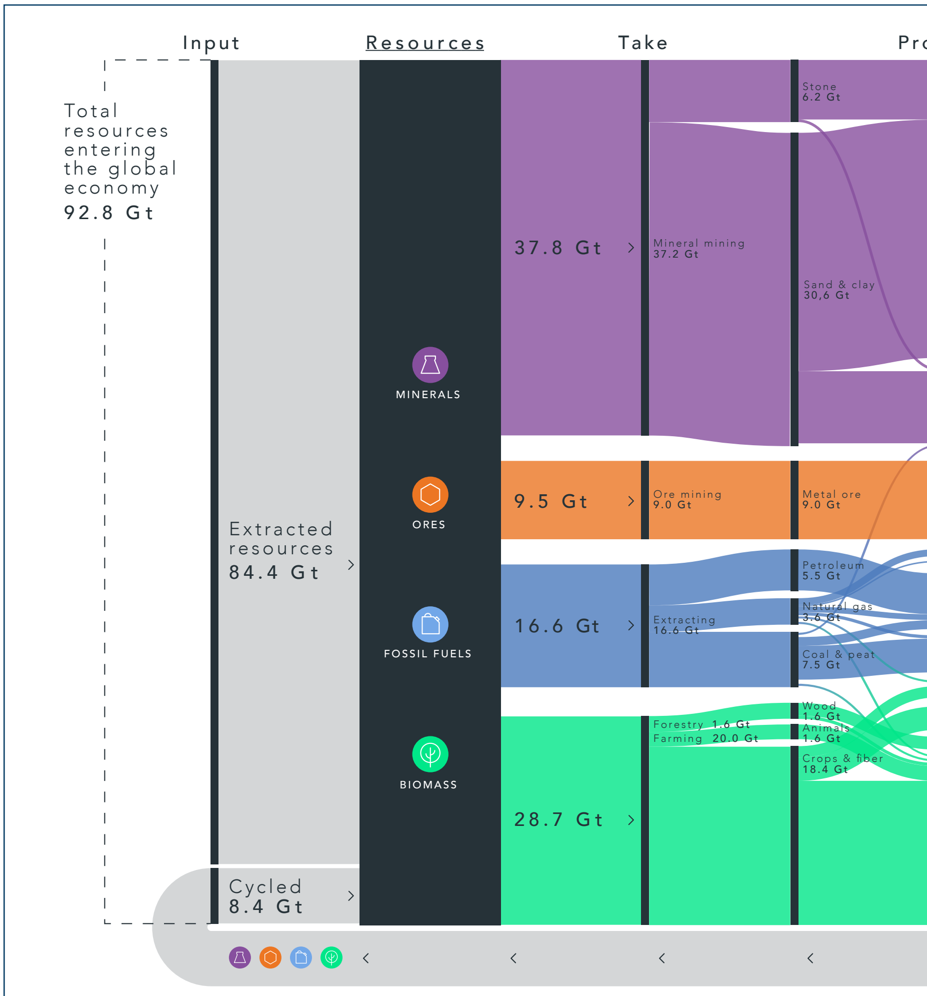


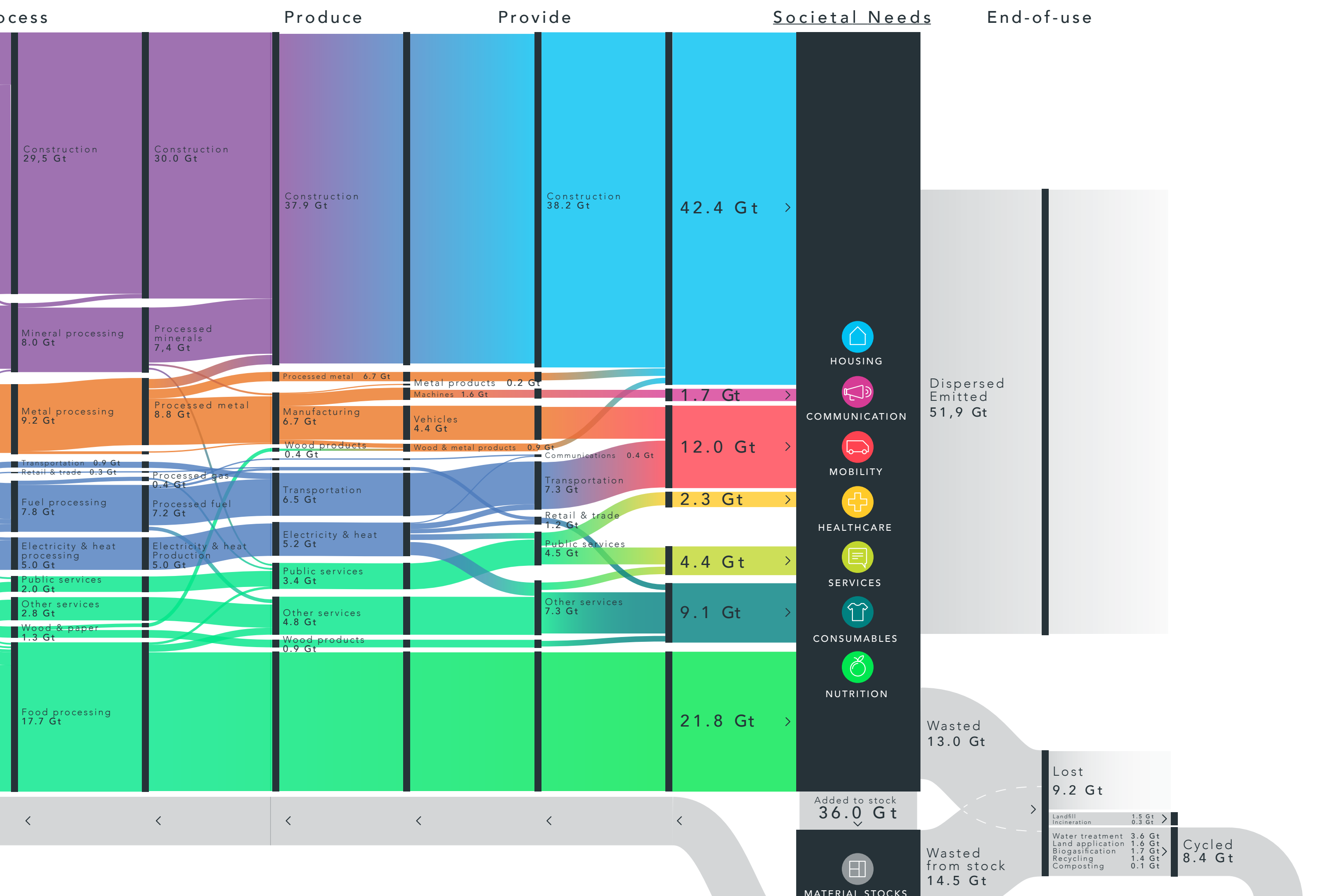

**Figure 1: The Global Resource Footprint Behind Satisfying Key Societal Needs**
The global metabolism, showing the flows of biomass, fossil fuels, metals, and
(Source: "The Circularity Gap Report," Circle Economy, January 2018, *http://www.sh*

prominent in emerging and developing countries that are building their infrastructures. Construction materials can only be recovered when structures reach the end of their service time. The amount of concrete from demolished stocks is estimated to be half of the total 14.5 billion tonnes of annually discarded stocks.[20]

Nutrition is the second-highest need, which is met with organic materials, typically food. Considerable amounts of food products and animal feedstock travel large distances to their consumers. Although nutrients can be recovered, the large distance between production and consumption complicates the closure of nutrient cycles.

Mobility is the third–highest need, where materials use consists of the metals in vehicles and the fossil fuels used to propel them. Fossil fuels are an estimated 20 percent of the resources extracted. They have an inherently linear character, as they are mostly used to provide energy and have no material value to society after combustion. In terms of recovery of vehicle components and materials, the transport sector is performing relatively well.

*From 1970 to 2010, global material extraction tripled, and population and economic growth are expected to push the amount of resources extracted to 186 billion tonnes per year by 2050.*




minerals from source to where they cater to the needs of society.
*iftingparadigms.nl/projects/the-circularity-gap-report/)*

### Box 2: Societal Needs and Desires

It is important to understand that the excessive growth in material use has partly been deliberate government policy and corporate strategy. Growth in material demand is driven by the notion that consumption and possession are sound approaches to the pursuit of happiness. This notion has its origins in the 20th century, when motivational research was used to accelerate consumption and to make sure that the expanded productivity resulting from the new mass production systems was met with sufficient product demand from society.[21] "The understanding of people's deepest desires or the "unconscious" was used to improve the effectiveness of product marketing. Arguably, this has transformed modern society from workers who produced to meet people's needs, into societies of consumers that produced to meet people's desires. [22]

Faced with the devastating environmental consequences of linear economies, it is time to shift societies to where the pursuit of happiness is decoupled from material possession and consumption. Only then can rebounds be avoided. Rebounds occur when savings on material and energy use are reinvested in activities that require more materials and energy. By challenging the underlying societal values behind consumerism and ownership as an effective means to provide services, a circular economy provides the opportunity to address the drivers behind excessive consumption and disposal.

Prospects for circular economies are supported by millennials, a generation that has developed different perceptions around ownership and whose members are the first digital natives.[23]

*From 1900 to 2010, global material stocks increased 23-fold, reaching 792 billion tonnes in 2010.*

## The Transition to a Circular Economy

### Circular Economy Strategies

Circular economy strategies aim to decouple economic growth, or rather human well-being, from resource use, making material use regenerative rather than depletive. It does so by proposing strategies that reduce the input of virgin materials, improve the use of existing assets, and reduce the output of harmful waste. The main strategies to achieve this are:

1. **Recovery and reuse** of waste and by-products as inputs for other uses. Examples include the collection of coffee grounds to produce mushrooms in the Netherlands,[24] the remanufacturing of cars in the Kumasi industrial cluster in Ghana,[25] the recovery of energy and nutrients from manure in Laos,[26] or various platforms that connect supply and demand of second-life products and materials.[27]

2. **Regenerative material sourcing** that avoids the creation of harmful waste. An example is biodegradable packaging materials.[28]

3. **Lifetime extension** of products and assets through a greater focus in the design and use phases of maintenance, upgrade, and repair, as well as reverse logistics, product takeback, and remanufacturing.

4. **Sharing and service models** that offer products as a service through pay-per-use models and employ sharing and leasing platforms to maximize the use of products and assets. Examples of sharing models that mobilize underused assets include sharing platforms for tools like Peerby, sharing models for cars like Snappcar, or rental services that use parked cars at airports like Parkflyrent.[29] Other examples of service models are the provision of lighting as a service rather than the sale of light bulbs, whereby the service provider also takes care of maintenance and payment of energy bills. This approach is gaining momentum with municipalities.[30] Other examples are paying for the use of jet engines and marine vessels by the hour, rather than selling the engines to the users.[31]

5. **Digitization** that helps dematerialization by replacing physical products with online equivalents or services, like videoconferencing or replacing supermarkets with a low-carbon grocery delivery service,[32] and using the internet of things to optimize resource use and maximize value.[33] In this way, digitization is an enabler of the above strategies. For instance, sensors can enable timely servicing and maintenance of products, avoiding downtime in use, particularly around leased products.

6. **Circular design** of products and assets that minimizes resource use throughout the product life cycle. Examples are modular design and design for disassembly, at the level of buildings[34] or even phones,[35] or labeling products on their eco-efficiency, like energy efficiency labeling.

Tapping into renewable sources of energy is also a circular economy strategy. However, since the added value in climate policy lies in its material and asset use strategies, energy-related strategies are left aside in this policy paper.

### Box 3: Aiming for Paradigm Shift

Circular economy strategies aim for nothing less than a paradigm shift. Mobility offers a convincing example of what this means. Environmental legislation and corporate initiatives have improved the fuel efficiency of cars but failed to improve the efficiency of the system in which cars provide mobility to society. Considering the amount of time a car is parked, stuck in traffic, or searching for a parking space, and combining this with the average occupancy rate of its seats, cars have a stunning utilization rate of as little as 2 percent. Looking at fuel use, the average deadweight ratio of a car is 12:1, and only 12 percent of its fuel use is converted into kinetic energy. These figures tell us that only 2 percent of the chemical energy in a car is used to transport people.[36] This shows that improving engine efficiency can only address a small part of the issue.

Moving to a circular economy seems a herculean task, but the transition to renewable energy shows it is possible. Renewable energy technologies are fighting an uphill battle against their fossil incumbents since fossil fuel subsidies still far exceed subsidies paid out to renewables.[37] Still, the transition is happening, and at an unprecedented pace. Large power companies are selling off their coal-fired assets, and investments in renewables exceed investments in fossil-fired assets.[38]

The circular economy will see the same development. It also fights an uphill battle against unfavorable tax regimes where linear businesses are seldom held accountable for these impacts. Still, like with the energy transition, an increasing number of companies see the transition to a circular economy as a prerequisite for securing access to resources, maintaining society's license to operate, or merely for continuing commercial success. The latter argument is confirmed by various modeling exercises that confirm that the circular economy makes economic sense.[39]

## Circular GHG-Mitigation Options

Sixty-seven percent of global emissions are related to material management: the extraction, processing, transportation, and disposal of stuff (figure 2). The remaining minority share of GHG emissions stem from passenger transport and thermal comfort in residential and commercial buildings.

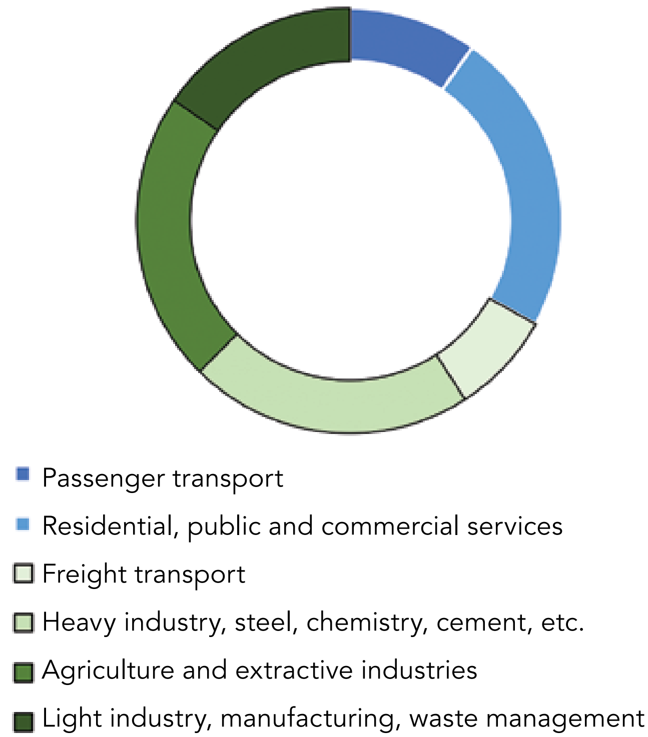


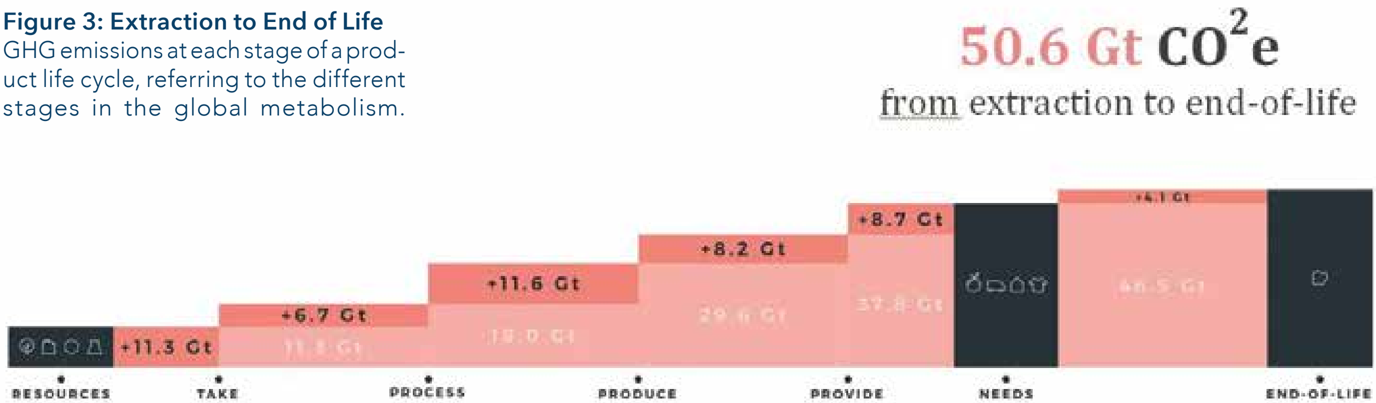

**Figure 2: GHG Service Categories**
Overviews of emissions per sectors in which emissions from the energy sector are proportionally allocated to the end users of the energy supplied. (Analysis based on Bojana Bajželj et al., "Designing Climate Change Mitigation Plans That Add Up," Environmental Science & Technology. Vol. 47, No. 14, July 16, 2013, pp. 8062–69, accessed February 16, 2018, *https://doi.org/10.1021/es400399h*)

The extraction, processing, use, and eventual disposal of materials require a large amount of energy, which is mostly met with fossil fuels. Figure 2 shows that a significant portion of GHG emissions take place at the extraction, processing, and production stages. Keeping products and materials in circulation can reduce, or even avoid, emissions during production, all the way upstream to the fields, forests, mines, and quarries from which materials originate.

The following levers are key to how the circular economy reduces GHG emissions:

- **Prioritizing secondary materials:** An analysis of 53 products and materials showed that for 49 of them, using recycled resources decreases GHG emissions

**Figure 3: Extraction to End of Life**
GHG emissions at each stage of a product life cycle, referring to the different stages in the global metabolism.




by 1.4 tonnes, per tonne of product, compared to producing the same amount of product with primary resources.[40] New technologies are also emerging to help recycle more materials, such as the development of a process for recycling concrete.[41] This process breaks only the hydrated cement but not the gravel and sand, which allows the recycling of cement at the level of its composite elements. Since only up to 50 percent of the cement in concrete is hydrated, it also recovers cement that can be used to produce new concrete without further processing. Combining this with 3-D printing technology can dramatically reduce the amount of concrete required in a structure.[42] Concrete is second only to water in terms of global resource extraction, while it also represents a major secondary source. About half of the annual 14.5 billion tonnes of material released from stock demolition is concrete.[43] The cement industry itself is responsible for 5 percent of global GHG emissions.[44]

- **Prioritizing low-carbon materials:** Investment choices determine GHG emissions for many decades. As unprecedented growth in renewable energy capacity has prioritized regenerative sources of energy, the same will have to be done for materials. For instance, the use of alternative construction materials, like cross-laminated timber, has excellent potential. By gluing timber plates at an angle of 90 degrees, a light but strong construction material can be made. This material is strong enough to construct 10-story buildings, and according to some designers, it can support 300-meter-high skyscrapers.[45] What is interesting about cross-laminated timber is that it avoids the emissions associated with the production of cement and steel and even turns the carbon-intensive construction industry into a net carbon sink. Estimates for a nine-story building in London, which uses 950 cubic meters of wood, are that it has a carbon footprint that is lower than a comparable concrete structure by 1,080 tCO2e. Cross-laminated timber with sustainably sourced wood can also shorten construction time and perhaps even improve comfort and energy efficiency.[46] Since cross-laminated timber is a lot lighter than reinforced concrete, the foundation of these buildings can also be lighter. In cases where concrete remains the preferred construction material, it should be applied in modules so that the valuable concrete building blocks can be recovered and reused at the end of the structure's life.

- **Closing nutrient cycles:** The closure of nutrient cycles combines source separation with anaerobic digestion of manure, organic waste, and wastewater with nutrient recovery and application on land. Through land application, this technology can avoid soil degradation. Current digestion capacity is sufficient only to process 0.5 percent of global organic waste.[47] Expanding this capacity is an opportunity that can build on existing agricultural and environmental experience and initiatives in both developing[48] and developed countries.[49] Increasing this capacity will make large amounts of biogas available as a renewable energy source and can reduce demand for synthetic fertilizers and emissions from manure management. The production of fertilizer is responsible for approximately 1.2 percent of global GHG emissions alone,[50] while additional nitrous oxide emissions occur during the application of synthetic fertilizers. Furthermore, effective manure management in digesters can reduce methane emissions, which account for 0.5 percent of global GHG emissions.[51]

- **Optimizing the use of active assets:** Extracting more economic value or optimizing the service level that existing active assets can provide is another way the circular economy can have a lower carbon footprint than the current linear approach. The only issue that should be borne in mind is that sometimes older assets are less energy efficient, though there are ways this can be addressed. Asset sharing and service models, for example, hold a lot of potential to improve car use. Intensified usage will shorten a car's lifetime in terms of year (but not in terms of miles, since improved maintenance by the service provided might help extend the mileage individual cars can provide). This is a major opportunity to accelerate the replacement of the car fleet with newer and more-efficient models, or accelerate fuel switch to electricity or hydrogen.

- **Activating hibernating assets:** By 2010, humanity had already built up a stock of 792 billion tonnes of materials stored in assets and products with a long service time, like infrastructure, buildings, and vehicles. A significant amount of this stock is composed of hibernating assets, such as abandoned buildings and infrastructure, but also things like unused products in people's homes.[52] Bringing these products and materials back into circulation allows the replenishment of some of the material losses that are perhaps inevitable even in a fully circular economy, and without generating the emissions associated with primary sourcing of materials.
- **Designing for the future:** Finally, when products are properly designed, their reuse, remanufacturing, and recycling can be optimized. For example, Fairphone manufactures a modular phone in which broken elements can easily be replaced,[53] and many components are made of biodegradable materials.[54]

### Box 4: The Mitigation Potential of Circular Economy Strategies

**Worldwide:** The UNEP International Resource Panel estimates that a resource efficiency development trajectory could reduce global resource use (excluding water) 28 percent while reducing GHG emissions a staggering 72 percent and still supporting economic growth.[55]

**India:** The Ellen MacArthur Foundation estimated that in India, a circular development pathway would reduce GHG emission 40 percent compared to business as usual.[56]

**Five EU member states:** The Club of Rome compared development scenarios for five EU member states and found that renewable energy and energy efficiency alone can reduce GHG emissions 50 percent for them. When adding circular economy strategies, that number increases to 70 percent.[57]

In most of the examples above, like cement and fertilizer use, the intervention reduces the demand for carbon-intensive products rather than trying to make their production more efficient. That is reducing the cause of emissions rather than the source.

## Circular Economy Policies

Governments have a crucial role to play in the transition to a circular economy. Current policy and tax systems are predominantly designed to support the growth of a linear economic system with a focus on turning natural resources into capital. This aggravates many environmental challenges. Unless this is resolved, renewable energy implementation and the transition to a circular economy are difficult, regardless of subsidies and incentives in place.

Policymakers in China and the EU are the most vocal on circular economy policies, and both consider securing continued access to raw or recycled materials a condition for future economic growth. Here are some leading examples of circular economy policies:

1. The 2009 Circular Economy Promotion Law in China[58] laid the foundation for a series of action plans at the industry level.
2. Tax reduction on repair activities in Sweden, like the reduction of value-added tax from 25 percent to 12 percent on the repair of bicycles, household appliances, and clothes, encourages the maintenance of current stocks.[59]
3. The Dutch target a fully circular economy by 2050, and to reduce raw material consumption by 50 percent by 2030. In addition, the Dutch government recognized that some legislation stands in the way of progress and designated areas that are exempt from certain legislation to support circular innovation.
4. The EU Circular Economy Package, a communication[60] and action plan,[61] brings together a set of targets and initiatives into a single plan for a transition to a circular economy.
5. The EU Ecodesign Directive defines rules for improving the environmental performance of products through improved design, targeting household appliances, and information and communication technologies.
6. The EU *Buying Green!*[62] handbook for public procurement promotes practices that support the circular economy.
7. The German Resource Efficiency Programme II aims to monitor national resource efficiency and permanently reduce the consumption of raw materials.

## Circular Economy Concepts Supporting the Paris Agreement

Despite their potential, circular economy strategies and underlying metabolic analysis are only used by a few countries and cities in the development of GHG-mitigation strategies, mostly in Europe and Asia (figure 4). In a metabolic analysis, materials and energy flows are mapped to develop an understanding of how these flows meet societal needs.[63] This allows countries to identify additional circular mitigation opportunities that potentially cut across sectors and national borders.[64] An analysis of a selection of the NDCs and of the Clean Development Mechanism (CDM) project pipeline shows that there is ample potential to increase mitigation ambition through circular economy strategies.

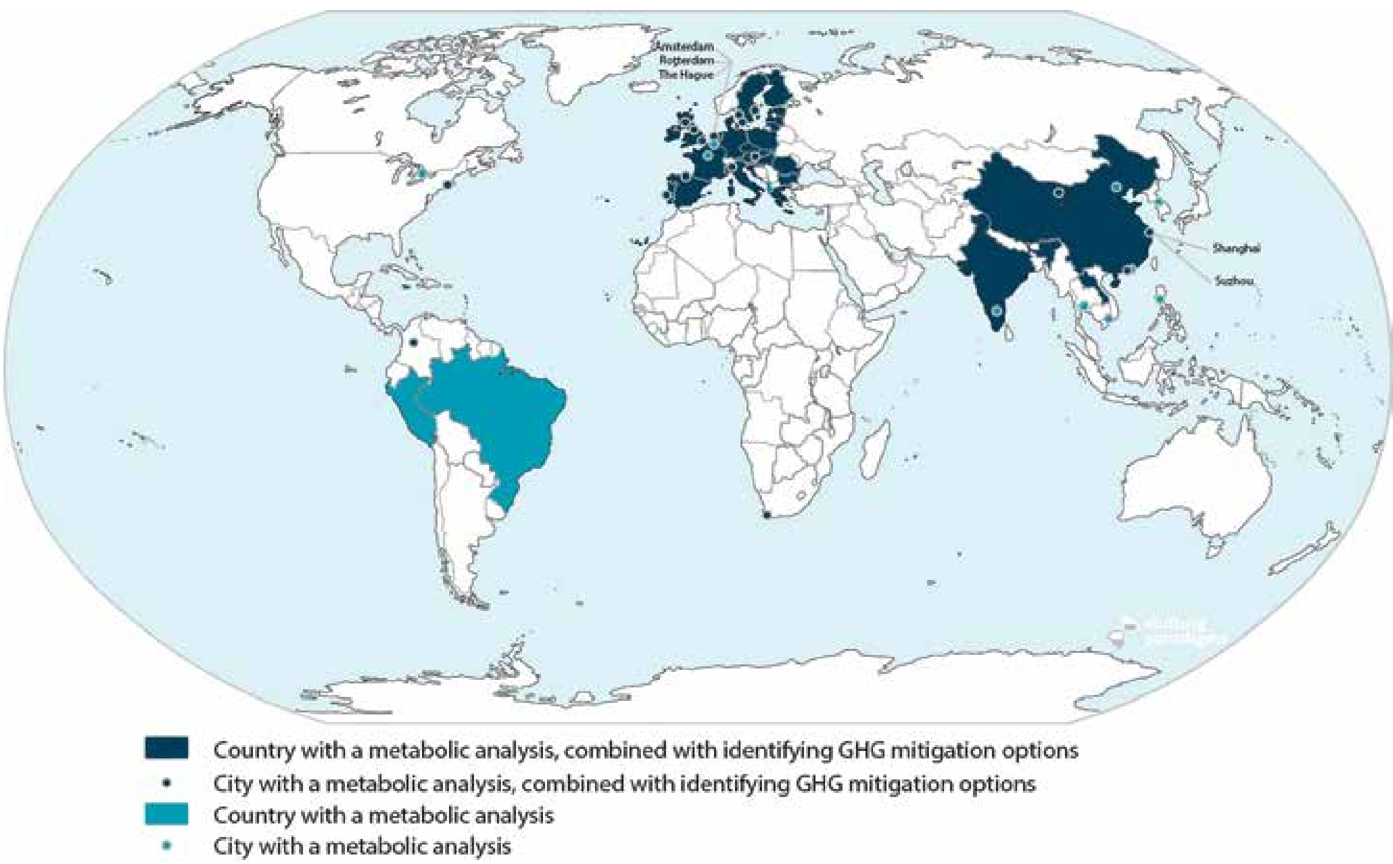
## National Climate Policy Pledges

Examining the NDCs of a few of the larger economies on each continent—China, India, the EU, South Africa, Brazil, and the United States—shows that only China and South Africa make reference to resource efficiency or circular economy to reduce GHG emissions.

In fact, explicit references to circular economy appear only in the NDCs from China, Burkina Faso, Monaco, the Seychelles, and Barbados. The Chinese NDC is most explicit, connecting its mitigation ambition with the actual structure and layout of its economy and consumption patterns rather than only trying to improve the efficiency of existing assets. It states that "resource conservation and environmental protection have become the cardinal national policy, placing mitigation and adaption on equal footing." China's NDC also refers to

**Figure 4: Cities and Countries–Circle Economy Scans and GHG**

Overview of countries and cities that completed a metabolic analysis and those that used such an approach to identify GHG-mitigation opportunities.




The graph gives an overview of metabolic analyses that have been undertaken but is not comprehensive. (Sources: Metabolism of Cities, *https://metabolismofcities.org*; Circle Economy, *http://www.circle-economy.com*; Ellen MacArthur Foundation, *http://www.ellenmacarthurfoundation.org*; Researchgate, *http://www.researchgate.net*; Asian Development Bank, *http://www.adb.org*; FABRIC *http://www.fabrications.nl*; Chatham House, *https://goo.gl/Fy3ZP8*; and Shifting Paradigms, *http://www.shiftingparadigms.nl*) a continued restructuring of the economy and improved recycling. Targeting the demand side, the NDC even refers to green public procurement and to curbing "extravagance and waste."[65]

References to resource use appear in the Indian NDC, which quotes Mahatma Gandhi on the wise use of natural resources and refers to avoiding resource exploitation and strengthening the resource base of the rural economy. The South African NDC connects the climate change issue with an "overuse of global commons in an unequal world."[66] This applies to fossil fuels as well as to raw materials. The focuses of the mitigation measures described in the NDC are on the energy and transport sectors, leaving the mitigation potential of decreasing the resource base on which the country relies mostly untapped.

## Integrate Circular Economy and Climate Policies

Many governments have adopted legislation to improve waste management—just one aspect of circular economy and often not tied to climate policy—but few have adopted legislation that tries to reduce waste holistically and at the source or in conjunction with climate action. Circular economy policies targeted to the source of waste include lifetime extension, modular design, design for disassembly, material and resource passports, and international cooperation on supply chains.

In a transnational example of circular economy and climate policies working in tandem, an expert review of European policies pointed at three policies as being the most effective,[67] to which tax reform should be added as an important enabler:

1. **The EU's Ecodesign Directive** establishes a framework of ecodesign requirements for energy-related products. The 2016-19 working plan includes contributions to the Circular Economy Action Plan. The Ecodesign Directive can be further improved by including material efficiency.

2. **Extended producer responsibility** schemes introduce life-cycle thinking in manufacturing, in supporting the marketing of better products, and in promoting responsible interaction between producers and consumers. They have proven to be effective in the European Union and in front-running countries such as France.

3. **Incentives for green public and private procurement** help create demand for circular products.[68]

4. **Tax reform, from labor to resource extraction,** can make it more attractive for companies to adopt circular business models, even if these are more labor intensive. For example, targeted tax reform might require redesign, reverse logistics, sorting, or improved maintenance to extend a product's service life or recover products and materials at the end of their lifetime. According to Ex'tax and Cambridge Economics, shifting 13 percent of labor tax to resource use and disposal in the EU would reduce greenhouse gas emissions by 8.2 percent and boost employment 2.9 percent.[69] This concept is supported by organizations like the International Monetary Fund[70] and the Organisation for Economic and Co-operative Development (OECD),[71] and it made it onto the agenda of coalition negotiations in the Netherlands in 2017 and Sweden, where a reduction of taxes on repair activities has been announced.[72]

## Refocus International Cooperation

After the success of the Paris Agreement, the signatory countries are working to put the principles of the agreement into practice and develop the underlying mechanisms and procedures. These will help support investments in low-carbon technologies, encourage technology transfer, and help build capacity to identify and enable the mitigation of GHG emissions. From a circular economy perspective, there are four major opportunities for climate policymakers and international cooperation on climate action to elevate national mitigation ambition under the Paris Agreement:

1. **Complement existing mitigation approaches with approaches that target the cause of emissions.** The focus on GHG emission sources has made GHG emission reductions in the industry and energy sectors possible. However, this focus has also diverted attention from developing alternatives to certain carbon-intensive industries. In the energy sector, the rise of renewable energy has started to make fossil fuel assets obsolete. It is time to aim for a similar shift to low-carbon and regenerative materials, close nutrient cycles to reduce dependence on chemical inputs from fossil origin, and use materials that have a net sequestration impact.

2. **Identify new mitigation options with consumption-based accounting.** Cities and the Intergovernmental Panel on Climate Change have taken steps toward carbon accounting based on a life-cycle approach.[73] Such approaches reveal and encourage mitigation actions through international cooperation along material value chains. An estimated 20 to 30 percent of a nation's carbon footprint lies in the emissions embedded in the products crossing its borders.[74] For the EU, the ClimateWorks Foundation estimates that territorial emissions are on track to decrease 20 percent in 2020 compared to 1990. However, consumption-based emissions, estimated with a life-cycle approach, have increased by 11 percent, mostly because of broadened trade flows with China after it joined the World Trade

Organization.[75] The territorial approach to carbon accounting of the United Nations Framework Convention on Climate Change (UNFCCC) does not incentivize a government to take domestic actions that can reduce emissions in another country.

3. **Allocate climate finance to circular mitigation opportunities.** The UNFCCC process also mobilizes and directs large amounts of climate finance into mitigation and adaptation activities. Climate finance rarely targets low-carbon materials and dematerialization strategies. It does not reflect that two-thirds of global GHG emissions are linked to material management. To enable these investments requires developing a better understanding of the mitigation impact of improving resource efficiency.

4. **Use metabolic approaches to identify mitigation options.** Finally, capacity building should step away from a focus on the sources of emissions to developing an understanding of how resources, both raw materials and fuels, are used to deliver services to society. This requires a metabolic analysis, a mapping of the flows and stocks of materials and energy in a jurisdiction,[76] aiming for improvement of the system and the way it responds to societal needs.

At the national level, Laos just completed an analysis of cross-sectoral circular economy strategies that could contribute to GHG emissions reductions within the country and along the international supply chains to which it is connected.[77] The countries and cities that undertook a metabolic analysis to identify opportunities for cross-sectoral circular economy strategies that reduce emissions across borders is increasing and extends beyond the early movers like India,[78] Albania,[79] Brussels,[80] Rotterdam,[81] and Glasgow.[82] Because of their potential to elevate the mitigation ambition of the Paris Agreement, metabolic approaches should become a cornerstone of capacity building on climate action.

The benefits of a circular economy go beyond mitigation action alone, aiming to make vital services like mobility, shelter, and nutrition available to more people at lower cost in financial, environmental, and social terms. By closing material cycles, extending the responsibility of producers beyond the point of sale, and adjusting tax systems and the way GHG-mitigation options are identified, it is possible to target emissions at their root causes. Thus the circular economy offers a promising pathway to a low-carbon society that has made progress on a broad range of SDGs and their underlying indicators.

## Endnotes

1 "The Emissions Gap Report 2017," United Nations Environment Programme (UNEP), 2017, accessed February 16, 2018, *http://www.unep.org/emissionsgap/.*

2 Fridolin Krausmann, Marina Fischer-Kowalski, Heinz Schandl, and Nina Eisenmenger, "The Global Sociometabolic Transition," Journal of Industrial Ecology, Vol. 12, No. 5–6, October 1, 2008, pp. 637–56, accessed February 16, 2018, *https://doi.org/10.1111/j.1530-9290.2008.00065.x*.

3 "Circular Economy Strategies for Lao PDR," United Nations Development Programme (UNDP), October 2017, accessed February 16, 2018, *http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/circular-economy-strategies-for-lao-pdr.html*.

4 Stefan Bringezu et al., "Assessing Global Resource Use: A Systems Approach to Resource Efficiency and Pollution Reduction," report of the International Resource Panel, United Nations Environment Programme, 2017, Nairobi, Kenya, accessed February 16, 2018, *http://www.resourcepanel.org/sites/default/files/documents/document/media/assessing_global_resource_use_full_report_final_web_281117.pdf*.

5 "Five Ways the Circular Economy Can Raise the Ambition of Climate Policies and Strategies," Shifting Paradigms, accessed February 16, 2018, *http://www.shiftingparadigms.nl/articles/blog-24-five-ways-the-circular-economy-can-raise-the-ambition-of-climate-policies-and-strategies/*.

6 "Policy Levers for a Low-Carbon Circular Economy," European Climate Foundation, 2017, accessed February 16, 2018, *http://www.shiftingparadigms.nl/projects/policy-levers-for-a-low-carbon-circular-economy/*.

7 "Emissions Gap Report," UNEP, 2017.

8 Ibid.

9 "Implementing Circular Economy Globally Makes Paris Targets Achievable," Circle Economy, June 28, 2016, accessed February 16, 2018, *http://www.circle-economy.com/circular-economy-a-key-lever-in-bridging-the-emissions-gap-to-a-1-5-c-pathway/.*

[10] "Circular Jobs: The Circular Economy and Opportunities for Employment in the Netherlands," Circle Economy, March 22, 2017, accessed February 16, 2018, *https://www.circle-economy.com/the-circular-economy-at-work/#.WkT3A1XiZhE.*

[11] Bringezu et al., "Assessing Global Resource Use."

[12] See Sustainable Development Knowledge Platform, United Nations, accessed February 16, 2018, *https://sustainabledevelopment.un.org/sdgs.*

[13] "The Circularity Gap Report," Circle Economy, January 2018, accessed February 16, 2018, *http://www.shiftingparadigms.nl/projects/the-circularity-gap-report/.*

[14] "Global Materials Flows and Resources Productivity: Assessment Report for the UNEP International Resource Panel," UNEP, 2016, accessed February 16, 2018, *http://www.resourcepanel.org/reports/global-material-flows-and-resource-productivity*.

[15] UNEP, "Resource Efficiency: Potential and Economic Implications," report for the International Resource Panel, March 2017, accessed February 16, 2018, *http://www.resourcepanel.org/reports/resource-efficiency.*

[16] Fridolin Krausmann et al., "Global Socioeconomic Material Stocks Rise 23-Fold Over the 20th Century and Require Half of Annual Resource Use," Proceedings of the National Academy of Sciences, Vol. 114, No. 8, February 21, 2017, pp. 1880–85, accessed February 16, 2018, *https://doi.org/10.1073/pnas.1613773114*.

[17] Ibid.

[18] "Circularity Gap Report," Circle Economy.

[19] Stefan Paulik and Daniel B. Müller, "The Role of In-Use Stocks in the Social Metabolism and in Climate Change Mitigation," Global Environmental Change, Vol. 24, January 1, 2014, pp. 132-42, accessed February 16, 2018, *http://dx.doi.org/10.1016/j.gloenvcha.2013.11.006.*

[20] Krausmann, "Global Socioeconomic Material Stocks."

[21] Stefan Schwarzkopf and Rainer Greis, eds., *Ernest Dichter and Motivation Research: New Perspectives on the Making of Post-War Consumer Culture* (New York: Palgrave Macmillan, 2010).

[22] Laurence R. Samuel, *Freud on Madison Avenue: Motivation Research and Subliminal Advertising in America* (Philadelphia: University of Pennsylvania Press, 2013).

[23] See Goldman Sachs, "Millennials Coming of Age," accessed February 16, 2018, *http://www.goldmansachs.com/our-thinking/pages/millennials/.*

[24] "Safe Mushrooms From Rotterdam's Coffee Grind," Wageningen University, May 26, 2015, accessed February 16, 2018, *www.wur.nl/en/newsarticle/Safe-Mushrooms-from-Rotterdams-coffee-grind.htm*.

[25] Hubert Schmitz, "Africa's Biggest Recycling Hub?" Institute of Development Studies, November 20, 2015, accessed February 16, 2018, *https://www.ids.ac.uk/opinion/africa-s-biggest-recycling-hub*.

[26] SNV, Netherlands Development Organization, "Domestic Biogas," accessed February 16, 2018, *http://www.snv.org/public/cms/sites/default/files/explore/download/snv_domestic_biogas_leaflet.pdf.*

[27] See Marktplaats, accessed *February 16*, 2018, *http://www.marktplaats.nl*.

[28] G. Davis and J. H. Song, "Biodegradable Packaging Based on Raw Materials From Crops and Their Impact on Waste Management," *Industrial Crops and Products*, Vol. 23, No. 2, March 1, 2006, pp. 147–61, accessed February 16, 2018, *https://doi.org/10.1016/j.indcrop.2005.05.004*.

[29] See Snapp Car, accessed *February 16*, 2018, *http://www.snappcar.nl*; Park Fly Rent, accessed February 16, 2018, *http://www.parkflyrent.nl*; and Peerby, accessed *February 16*, 2018, *http://www.peerby.com*.

[30] See Philips, "Connected Lighting for Smart Cities," accessed February 16, 2018, *http://www.lighting.philips.com/main/systems/connected-lighting/connected-lighting-for-smart-cities/lighting-and-infrastructure.*

[31] See Rolls Royce, "Power by the Hour," accessed February 16, 2018, *https://www.rolls-royce.com/products-and-services/marine/discover/2017/discover-power-by-the-hour.aspx.*

[32] See Picnic Online Supermarket, accessed February 16, 2018, *https://www.picnic.nl/.*

[33] Pablo Valerio, "How the Internet of Things Enables the Circular Economy," The ICT Scoop, accessed February 16, 2018, *https://theictscoop.com/how-the-internet-of-things-enables-the-circular-economy-fd98f43733ec.*

[34] Park 2020, a business area near Schiphol Airport, which follows the Cradle to Cradle principles, accessed February 16, 2018, *http://www.park2020.com*.

[35] Fairphone produces a modular phone and aims to have a fair supply chain, accessed February 16, 2018, *https://www.fairphone.com/en/.*

[36] Martin R. Stuchtey, Per-Anders Enkvist, and Klaus Zumwinkel, *A Good Disruption: Redefining Growth in the Twenty-First Century* (London: Bloomsbury Publishing, 2016).

[37] Richard Bridle and Lucy Kitson, "The Impact of Fossil-Fuel Subsidies on Renewable Electricity Generation," International Institute for Sustainable Development, December 2014, accessed February 16, 2018, *http://www.iisd.org/library/impact-fossil-fuel-subsidies-renewable-electricity-generation.*

[38] "Global Trends in Renewable Energy Investment 2017," UNEP, 2017, accessed February 16, 2018, *http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf.*

[39] Bringezu et al., "Assessing Global Resource Use"; "New Era. New Plan. Europe: A Fiscal Strategy for an Inclusive, Circular Economy," The Ex'tax Project, 2016, accessed February 16, 2018, *http://www.neweranewplan.com/*; "Circular Economy in India: Rethinking Growth for Long-Term Prosperity," The Ellen MacArthur Foundation, December 5, 2016, accessed February 16, 2018, *https://www.ellenmacarthurfoundation.org/publications/india*.

[40] Analysis based on David A. Turner et al., "Greenhouse Gas Emission Factors for Recycling of Source-Segregated Waste Materials," *Resources, Conservation and Recycling*, Vol. 105, December 1, 2015, pp. 186–97, accessed February 16, 2018, *https://doi.org/10.1016/j.resconrec.2015.10.026*.

[41] See Amsterdam Smart City, SmartCrusher, accessed February 16, 2018, *https://amsterdamsmartcity.com/products/smartcrushercircular-concrete-saving-co2*.

[42] See India Block, "'World's First' 3D-Printed Concrete Bridge Opens in the Netherlands," Dezeen, October 27, 2017, accessed February 16, 2018, *https://www.dezeen.com/2017/10/27/worlds-first-3d-printed-concrete-bridge-bicycles-bam-infra-netherlands/.*

[43] Krausmann, "Global Socioeconomic Material Stocks."

[44] Ernst Worrell et al., "Carbon Dioxide Emission From the Global Cement Industry," *Annual Review of Energy and the Environment*, Vol. 26, No. 1, November 2001, pp. 303-29, accessed February 16, 2018, *https://doi.org/10.1146/annurev.energy.26.1.303*.

[45] See Max Opray, "Tall Timber: The World's Tallest Wooden Office Building to Open in Brisbane," *Guardian*, June 20, 2017, accessed February 16, 2018, *http://www.theguardian.com/sustainable-business/2017/jun/21/tall-timber-the-worlds-tallest-wooden-office-building-to-open-in-brisbane*; and Daniel White, "This Huge Skyscraper Made of Wood May Rise in London," Time, April 8, 2016, accessed February 16, 2018, *http://time.com/4286667/london-wood-skyscraper/.*

[46] Haibo Guo et al., "A Comparison of the Energy Saving and Carbon Reduction Performance Between Reinforced Concrete and Cross-Laminated Timber Structures in Residential Buildings in the Severe Cold Region of China," *Sustainability*, Vol. 9, No. 8, August 12, 2017.

[47] Stuchtey et al., "Good Disruption."

[48] "The Circular Dairy Economy," Circle Economy, 2016, accessed February 16, 2018, *https://www.circle-economy.com/case/the-circular-dairy-economy/*.

[49] See Simgas biogas system, accessed February 16, 2018, *http://simgas.org/biogas-system/*; and SNV, Domestic Biogas, accessed *February 16*, 2018, *http://www.snv.org/sector/energy/topic/biogas.*

[50] "Fourth Assessment Report, Climate Change 2007: Working Group III Report, 'Mitigation of Climate Change,'" Intergovernmental Panel on Climate Change, 2007, Section 7.4.3.2, "Fertilizer Manufacture," accessed February 16, 2018, *https://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch7s7-4-3-2.html*.

[51] "Global Methane Emissions and Mitigation Opportunities," Global Methane Initiative, 2015, accessed February 16, 2018, *http://www.globalmethane.org/documents/analysis_fs_en.pdf.*

[52] Krausmann, "Global Socioeconomic Material Stocks."

[53] See Fairphone, accessed February 16, 2018, *https://www.fairphone.com/en/.*

[54] See The Circular Design, accessed February 16, 2018, *https://www.circulardesignguide.com/*.

[55] Bringezu et al., "Assessing Global Resource Use."

[56] "Circular Economy in India," Ellen MacArthur Foundation.

[57] Anders Wijkman and Kristian Skånberg, "The Circular Economy and Benefits for Society: Jobs and Climate Clear Winners in an Economy Based on Renewable Energy and Resource Efficiency," The Club of Rome, 2016, accessed February 16, 2018, *http://www.clubofrome.org/2016/03/07/a-new-club-of-rome-study-on-the-circular-economy-and-benefits-for-society/*.

[58] An English translation of the China Circular Economy Law is available at *https://ppp.worldbank.org/public-private-partnership/library/china-circular-economy-promotion-law*, accessed February 16, 2018; see also Will McDowall et al., "Circular Economy Policies in China and Europe," *Journal of Industrial Ecology*, Vol. 21, No. 3, June 1, 2017, pp. 651–61, accessed February 16, 2018, *https://doi.org/10.1111/jiec.12597*.

[59] Richard Orange, "Waste Not Want Not: Sweden to Give Tax Breaks for Repairs," *Guardian*, September 19, 2016, accessed February 16, 2018, *http://www.theguardian.com/world/2016/sep/19/waste-not-want-not-sweden-tax-breaks-repairs*.

[60] See "Towards a Circular Economy: A Zero Waste Programme for Europe," Communication from the European Commission to the European Parliament, 2014, accessed February 16, 2018, *http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0398R%2801%29.*

[61] See "Closing the Loop—An EU Action Plan for the Circular Economy," Communication from the European Commission to the European Parliament, 2015, accessed February 16, 2018, *http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614.*

[62] See *Buying Green!: A Handbook on Green Public Procurement*, European Commission, April 2016, accessed February 16, 2018, *http://ec.europa.eu/environment/gpp/buying_handbook_en.htm*.

[63] Krausmann et al., "Global Sociometabolic Transition".

[64] "Circular Economy Strategies for Lao PDR," UNDP.

[65] "Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions," United Nations Framework Convention on Climate Change (UNFCCC), accessed January 31, 2018, *http://www4.unfccc.int/ndcregistry/PublishedDocuments/China%20First/China%27s%20First%20NDC%20Submission.pdf.*

[66] "South Africa's Intended Nationally Determined Contribution," UNFCCC, accessed January 31, 2018, *http://www4.unfccc.int/ndcregistry/PublishedDocuments/South%20Africa%20First/South%20Africa.pdf.*

[67] Matthieu Bardout and Jelmer A. Hoogzaad, "Policy Levers for a Low-Carbon Circular Economy," Circle Economy, 2017, accessed February 16, 2018, *http://www.shiftingparadigms.nl/projects/policy-levers-for-a-low-carbon-circular-economy/*.

[68] Ibid.

[69] "New Era. New Plan," Ex'tax Project.

[70] See Jeff Danforth et al., "IMF Survey: Strong and Equitable Growth: Fiscal Policy Can Make a Difference," International Monetary Fund, June 30, 2015, accessed February 16, 2018, *http://www.imf.org/en/news/articles/2015/09/28/04/53/sopol063015a.*

[71] See "Tax and the Environment," Organisation for Economic Co-operation and Development, accessed February 16, 2018, *http://www.oecd.org/tax/tax-policy/tax-and-environment.htm.*

[72] Orange, "Waste Not."

[73] Peter-Paul Pichler et al., "Reducing Urban Greenhouse Gas Footprints," *Scientific Reports*, Vol. 7, No. 1, article no. 14659, November 7, 2017, accessed February 16, 2018, *https://doi.org/10.1038/s41598-017-15303-x*.

[74] This estimate varies between different sources. See Paulik and Müller, "The Role of In-Use Stocks," and Glen P. Peters et al., "Growth in Emission Transfers Via International Trade From 1990 to 2008," *Proceedings of the National Academy of Sciences*, Vol. 108, No. 21, May 24, 2011, pp. 8903–8, accessed February 16, 2018, *https://doi.org/10.1073/pnas.1006388108*.

[75] "Europe's Carbon Loophole," ClimateWorks Foundation, September 19, 2017, accessed February 16, 2018, *http://www.climateworks.org/report/europes-carbon-loophole/.*

[76] Timothy M. Baynes and Daniel B. Müller, "A Socio-Economic Metabolism Approach to Sustainable Development and Climate Change Mitigation," in *Taking Stock of Industrial Ecology*, ed. Roland Clift and Angela Druckman (Cham, Switzerland: Springer International Publishing, 2016), 117–35, accessed February 16, 2018, *https://doi.org/10.1007/978-3-319-20571-7_6;* Heinz Schandl et al., "Global Material Flows and Resource Productivity: Forty Years of Evidence," *Journal of Industrial Ecology*, June 30, 2017, accessed February 16, 2018, *https://doi.org/10.1111/jiec.12626*.

[77] "Circular Economy Strategies for Lao PDR," UNDP.

[78] "Circular Economy in India," Ellen MacArthur Foundation.

[79] George Brugmans, Marieke Francke, and Freek Persyn, eds., "The Metabolism of Albania: Activating the Potential of the Albanian Territory," International Architecture Biennal Rotterdam, 2015, accessed February 16, 2018, *http://iabr.nl/nl/publicatie/albania_book.*

[80] Paul Duvigneaud and S. Denayeyer-De Smet, "L'Ecosystéme Urbain Bruxellois," in Productivité biologique en Belgique, ed. Paul Duvigneaud and Patrick Kestemont (Paris: Éditions Duculot, 1977), "Material Flow Analysis Diagram," accessed February 16, 2018, *http://mfadiagrams.blogspot.nl/2011/11/urban-metabolism-of-brussels.html.*

[81] Nico Tilly et al., eds., "Urban Metabolism: Sustainable Development of Rotterdam," International Architecture Biennal Rotterdam, 2014, accessed February 16, 2018, *http://iabr.nl/en/publicatie/stedelijk-metabolisme.*

[82] "Circular Glasgow: A Vision and Action Plan for the City of Glasgow," Circle Economy, 2016, accessed February 16, 2018, *https://www.circle-economy.com/glasgowcirclecity.*

THESTANLEYFOUNDATION

THE STANLEY FOUNDATION | 209 IOWA AVENUE, MUSCATINE, IA 52761 USA
563-264-1500 | 563-264-0864 FAX | INFO@STANLEYFOUNDATION.ORG

The Stanley Foundation advances multilateral action to create fair, just, and lasting solutions to critical issues of peace and security. Our work is built on the belief that greater international cooperation will enhance global governance and spur global citizenship. The foundation frequently collaborates with a wide range of organizations using different forums, formats, and venues to engage policy communities. We do not make grants.

Our programming addresses profound threats to human survival where improved multilateral governance and cooperation are fundamental to transforming real-world policy. Current efforts focus on policy improvement to prevent genocide and mass atrocities, eliminate the threat of nuclear terrorism, and drive collective and long-term action on climate change. The foundation also works to promote global education in our hometown of Muscatine, Iowa, and nearby.

A private operating foundation established in 1956, the Stanley Foundation maintains a long-term, independent, and nonpartisan perspective. Our publications, multimedia resources, and a wealth of other information about programming are available at *www.stanleyfoundation.org*.



PRINTED ON RECYCLED PAPER | 3/18 405