CLIMATE CHANGE MITIGATION THROUGH THE CIRCULAR ECONOMY

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CIRCLE ECONOMY
shifting paradigms

COLOPHON

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1. EXECUTIVE SUMMARY

This report from Circle Economy and Shifting Paradigms for the Scientific and Technical Advisory Panel (STAP), which advises the Global Environment Facility (GEF) on strategies, projects and policies, investigates how the circular economy can reduce greenhouse gas (GHG) emissions in low- and middle-income countries. It also uncovers the range of socio-economic and environmental co-benefits that circular mitigation interventions can bring to GEF countries of operation. It aims to provide strategic advice to the GEF and its implementing partners and carve out a role for these bodies in accelerating the transition to a low-carbon circular economy.

The topic of this report is a very timely one and supports what proponents of the circular economy have long suspected: emissions are inevitably tied to our use of material resources. Circle Economy's *Circularity Gap Report 2021* reported that circular economy strategies—which allow us to do *more* with *less*—implemented across sectors and nations, have the potential to slash global GHG emissions by 39%. It also finds that as much as 70% of emissions stem from material extraction, processing and handling,[2] enforcing the need for an approach that touts intelligent resource management. In being a means to an end for a socially just and ecologically safe space,[3] the circular economy also holds promise in delivering co-benefits such as biodiversity and job creation.[4]

However, while evidence confirms that the circular economy holds significant potential for emissions mitigation in Europe and G7 countries,[5 6] its impact on other parts of the world is less known. In these contexts, the circular economy is known by other terminologies such as green growth, sustainable production and consumption, sustainable development and resource efficiency. There are valuable lessons to learn on the application of circular economy principles in low- and middle-income countries, especially as the circular economy is not yet leveraged to its full potential in any part of the world.

While existing mitigation commitments—laid out in countries' climate blueprints, the Nationally Determined Contributions (NDCs)—primarily focus on increasing the share of renewables in the energy mix, improving energy efficiency, and halting land-use-related emissions from deforestation, room for improvement exists in the form of circular strategies, which tap into previously unexplored mitigation possibilities. This report makes a case for such strategies in sectors relevant to the work of the GEF including agriculture, forestry, renewable energy and waste, construction and transport.[7] The proposed interventions currently do not play a large role in the Kyoto Protocol's Clean Development Mechanism (CDM), which is seen as a 'trailblazer'[8] of global investments in GHG mitigation—highlighting the further potential for mitigation opportunities that complement measures under the CDM.

METHODOLOGY

This report has been guided by desk research, expert interviews, expert consultation meetings and consultation with the STAP and the GEF. Interventions were selected through a broad literature review, and further narrowed down based on their GHG mitigation potential, ability to reduce material resource extraction, scalability and provision of socio-economic and environmental co-benefits. The selected interventions were then clustered such that each group presents a tangible GHG mitigation potential, business case potential, barriers, enablers and co-benefits. The mitigation potential of each cluster, which was determined for GEF countries of operation, was scaled down based on global data from the Intergovernmental Panel on Climate Change (IPCC), Food and Agriculture Organization (FAO), United Nations Framework Convention on Climate Change (UNFCCC), Project Drawdown and the World Resources Institute (WRI).

THE MOST PROMISING CIRCULAR INTERVENTIONS FOR GEF COUNTRIES OF OPERATION

This report presents 12 interventions which may be relevant to the work of the GEF. These circular mitigation interventions were chosen based on their potential to go beyond existing climate action in the GEF countries of operation, and their ability to deliversocio-economic and environmental co-benefits (which are related to GEF's other focal areas of biodiversity, chemicals and waste, land degradation and international waters). The mitigation potential and business case potential for each intervention, described in more detail in the report, is given by the Figure below.

The proposed interventions are:

1. **Improved livestock management:** Reduce emissions from livestock through productivity improvements, improve manure management and introduce anaerobic digestion of manure.
2. **Regenerative crop production and agroforestry:** Invest in cropland management practices that regenerate soil health, and increase biodiversity and carbon sequestration, including the use of agroforestry and mixed cropping.
3. **Bioeconomy and bio-based materials:** Scale the mechanical and chemical processing of agricultural and forest residues to produce bio-based construction materials (and other industries).
4. **Reducing food losses from harvest to processing:** Enhance harvest methods and timing, and improve the capacity to safely store, transport and process food products.
5. **Reducing food waste at the retailer and consumer stages:** Reduce food waste through improved inventory management, the development of secondary markets for imperfect food products or products near their expiry date and improved value-chain management.
6. **Closing the loop on urban organic residues:** Recover and separate organic residues from urban solid waste and wastewater for composting, biogas production, water and nutrient recovery to support urban and peri-urban farming.
7. **Redesign, reuse, repair, remanufacture of products and recycling of glass, paper, metals and plastics:** Enhance the collection, sorting and processing of materials and recyclables, diverting waste from landfills and incineration to increase the availability of secondary resources.
8. **Making the renewable energy transition circular:** Implement a life-cycle approach to renewable energy generation and storage capacity through design for disassembly, improved repairability, circular business models and the use of recycled materials.
9. **Eco-innovation in industrial clusters and informal networks:** Apply industrial symbiosis approaches to industrial parks and create formal and informal networks to encourage the use of secondary resources across industries.
10. **Circular design in construction:** Design buildings for improved energy efficiency, and minimise waste in the construction process by applying passive design, and modular and offsite construction.
11. **Non-motorised and shared transport:** Prioritise non-motorised transport, vehicle sharing and public transport in urban development.
12. **Shifting to healthier and more sustainable diets:** Shift to healthy diets that bridge the nutrition gap for lower-income brackets, while curbing meat consumption by diversifying diets to include more plant or insect-based protein.

Figure 1 shows the business case potential and GHG mitigation potential of each of the interventions proposed, specifically for the GEF recipient countries. For two of the interventions literature did not provide a credible estimate of the GHG mitigation potential for the GEF recipient countries.

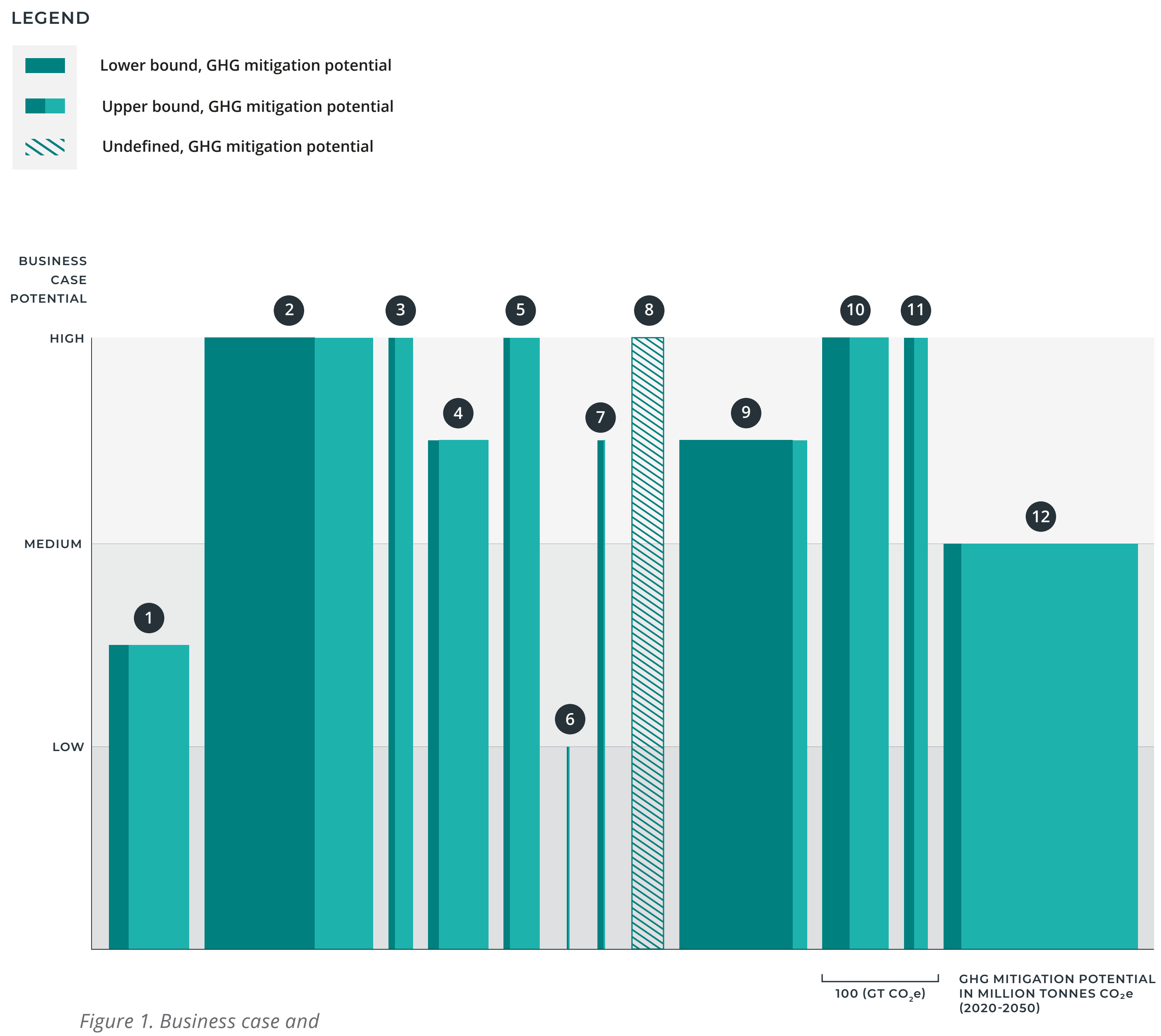


Figure 1. Business case and GHG mitigation potential

ACCELERATING THE TRANSITION TO A CIRCULAR ECONOMY

Synergies exist among all the chosen interventions in terms of their co-benefits, barriers and enabling conditions. Overall, the mitigation and business potential for the interventions proposed are significant. If applied, these strategies have the power to keep us on track for 1.5-degrees of warming and limit the impacts of climate change.

Mitigation potential
The 12 interventions have a joint mitigation potential of between 285 billion tonnes CO_2 equivalents (CO_2e) and 695 billion tonnes CO_2e between 2020 and 2050 respectively. Our remaining carbon budget for an ideal scenario—where we limit warming to 1.5-degrees—sits at 580 billion tonnes CO_2, highlighting the necessity for circular GHG mitigation strategies.

Co-benefits
As highlighted in the United Nations Environment Programme (UNEP) 2019 *Emissions Gap Report*, achieving climate goals will bring a myriad of other benefits in line with the Sustainable Development Goals. As our proposed circular strategies also focus on reducing primary material extraction and waste disposal, these co-benefits are even more pronounced.

Improved crop yields—and consequentially, higher revenues—food security, lower levels of air pollution, economic growth, the creation of fair and decent jobs and greater personal wellbeing emerged as socio-economic co-benefits of our interventions. Greater preservation of ecosystems, habitat protection that allows biodiversity to flourish and reduced water usage prevail as synergistic environmental co-benefits.

Barriers
The common barriers across the interventions emerged in distinctive categories: legal, regulatory and institutional, technological, cultural and economic and financial. The short-term planning horizons of national governments—which may disfavour policy that requires long-term investment and action—surfaced as a significant institutional barrier, as did policy that fails to consider systems-impact and afford attention to the potential knock-on effects of interventions. Cultural barriers were often interlinked with regulatory challenges: a short-term focus, for example, often means that more acute priorities (such as expanding housing stock) may be given precedence over environmental priorities, instead of being developed in tandem. Rising incomes may also lead to increases in consumption, especially due to cultural values that equate material consumption with success, showing a tendency towards consumption patterns and perceptions common to higher-income countries.

Technical barriers are often linked to economic ones: 'high-tech' circular interventions—such as those that require internet access or digitisation—may encounter challenges in countries with insufficient infrastructure. Meanwhile, low-tech measures—composting or regenerative agriculture—lack sufficient financial backing to get off the ground. This is especially the case in situations where the benefits from interventions, such as increased revenues or returns on investments, are not immediate. Financially speaking, the patience of funders and viability of circular business strategies were identified as barriers, as was the inadequate pricing of environmental externalities in goods, which fails to monetarily reward the benefits of circular initiatives. Funding circular interventions at scale—especially in the context of multilateral development banks—also poses challenges, while presenting an avenue for GEF projects to make a significant impact.

Enabling Conditions
Enabling conditions were found to coincide with barriers and ultimately boiled down to one key point: the benefits of circular strategies must be made clear to gain traction with decision-makers and those responsible for their implementation. Demonstration projects that show tangible benefits are needed to galvanise change—and communication on these benefits will increase the willingness to adjust, improve and scale policies. The co-benefits identified come back into play, as linking circular strategies to co-benefits that may be of greater political priority—like food security or job creation—may both inspire and enable swift action. To this end, all stakeholders should be involved in the policy creation process, matched by efforts to raise awareness, provide education and training and analyse how solutions can encompass all aspects of the value chain.

Additionally, standardised data collection and formalised insights on the drawbacks of the linear economy—presented along with the advantages of the circular economy—are crucial to advance circular solutions. Collection and analysis systems that provide detailed data on resource flows and feed them into reporting systems could both enable policymaking and national development strategies.

NEXT STEPS

Based on the findings above, the report presents 12 recommendations for guiding efforts in implementing circular projects with GHG mitigation potential to get us on track for 1.5-degrees of warming. The report provides tangible recommendations, highlighting the importance of a systems-based, highly participatory approach—involving donor countries, the private sector, businesses and communities—that will demonstrate the far-reaching impact circular strategies can offer.

While the proposed recommendations were developed in the context of the GEF, they are also applicable to other actors in the circular economy. The report finds that it is paramount to combine policy interventions with project support—for example by covering the cost difference between linear and circular approaches for a good or service—which can crucially prevent negative rebounds. It also emphasises the necessity to consider the embodied emissions in products that cross borders, in particular since these products are responsible for up to 30% of a country's consumption-based carbon footprint. Prioritising local materials, in an effort to both slash transport emissions and involve all actors along value-chains in project design, was also recommended; as was targeting and involving micro, small and medium-sized enterprises (MSMEs) along with the informal sector, which represent a large share of the labour market in GEF countries of operation. Finally, as finance was found to be a significant barrier, the report recommends tackling this challenge by implementing circular principles in its own procurement process, as well as developing cooperative and blended finance mechanisms to support and de-risk early investment in circular initiatives.

2.LOOKING BEYOND BORDERS: THE CIRCULAR GREENHOUSE GAS MITIGATION OPPORTUNITY

Climate change is a major global challenge that asks for unprecedented greenhouse gas (GHG) emissions reductions across international value chains to be addressed effectively. The Paris Agreement, established in November 2015, marked an important milestone in meeting that objective, yet progress and action to date is insufficient to meet internationally agreed-upon targets.

Consensus is also growing that incremental improvement, which is symptomatic of many of the Nationally Determined Contributions (NDCs), will not suffice and that transformational change is needed to achieve global goals.[9] The circular economy holds the promise for systemic transformation of our societies toward more resource efficiency and resilience.[10 11 12] A reality of the prevailing linear economy is that over-consumption has effectively become the norm, whilst elsewhere, minimum living standards are not even being reached. Therefore, any successful economic model that meets the needs of the society it serves while responsibly stewarding the natural systems upon which it is reliant should also encourage behavioural changes depending on context.

This report identifies and describes the role that the circular economy—when implemented with economically viable initiatives—can have in mitigating climate change along with socio-economic and environmental co-benefits. This includes providing strategic guidance and recommendations on potential projects, programmes, and activities that the GEF could consider in its future investments, and how to develop and implement these.

The opportunities identified consider the following premises, which should guide our thinking on the application of the circular economy as a mitigation lever.

These are:

1. **Exploring synergies.** The circular economy is a means towards reducing waste disposal and minimising the unsustainable extraction of primary resources. Climate change mitigation, on the other hand, is about reducing GHG emissions, whether they are CO_2 from fossil fuel combustion, methane emissions from livestock, waste management or wastewater treatment, or nitrous oxide from fertiliser application and hydrofluorocarbons from industry. This report explores where these two concepts are aligned, and where altering material flows to reduce excessive extraction and waste disposal is in line with the reduction of GHG emissions.

2. **Low carbon and material footprint.** The GEF countries of operation include low-income countries which have a relatively low per capita material and carbon footprint. When looking at the material footprint of consumption, they are also relatively circular since a large share of their material needs comes from regenerative resources in agriculture, forestry and fisheries. Circularity is defined as the share of materials in use on an annual basis which are from regenerative or secondary origin and which are cycled back into the system after reaching their end-of-life.[14] Where there are large (uncircular) mining operations, these often serve foreign demand.[15 16] Next to this, these countries often produce less waste per capita, while the waste that is disposed of is managed by a large group of (often informal) stakeholders.[17] Although their decentralised collection and processing of recyclables may give rise to concerns about labour conditions, health and safety, it does drive the circularity scoring up.

3. **Stock build-up.** Some of the GEF countries of operation are rapidly developing their infrastructure, buildings and vehicle fleets to be able to provide shelter, mobility and other services for a growing population with increasing material wealth. In the case of buildings and transport infrastructure, their service life typically extends for several decades. Where so-called *produced stock* is being developed, countries have an opportunity to develop infrastructure that supports a low-carbon future, allowing them to leapfrog toward societal models that are both circular and carbon neutral by design. Next to this, when reducing GHG emissions, there is a fine balance between maintaining existing assets, or accelerating their replacement with more energy-efficient technologies.[18]

4. **Detrimental linear flows.** On the other hand, the remaining linear material flows are very damaging. Most of the linear flows in low- and middle-income countries are from imported goods and materials, and their waste management systems are ill-equipped to handle such foreign materials. Examples are packaging waste, e-waste and hazardous waste. The unregulated disposal of these materials causes serious degradation of natural assets which threatens the long-term regenerative production capacity of the country, for which it relies on healthy soils, marine ecosystems and forests.[19 20]

5. **The informal sector.** Some low- and middle-income countries have thriving sectors that largely operate in the informal economy. These often involve smallholder farming, fishing, trading, and repair services, manufacturing and waste collection, sorting and management.[21 22] These small entrepreneurs jointly operate as a network, providing decentralised infrastructure for the production and dissemination of products and sometimes make up a larger share of the labour force than those employed by the large companies.[23 24]

6. **Resource rents.** The extraction of primary resources—both extracted minerals and agricultural or forestry products—often account for a large share of GDP and/or employment in low- and middle-income countries. National governments and international partners have often supported growth models that rely on the extraction of primary resources. According to Chatham House, 'Without meaningful dialogue at the national and international level around future growth pathways, there is a risk that natural resource-exporting countries will see the circular economy not as an opportunity for economic diversification but as a threat to continued growth.'[25]

7. **Value chain perspective.** Figure 2 shows that some 62% of global GHGs are emitted during the Take, Process and Produce stages.[26] Circular economy strategies that extend product and material lifetimes and use-intensity cut these emissions. This might require looking across borders,[27] since some of the emissions from extraction, processing and production may occur in countries other than the countries of consumption and disposal.

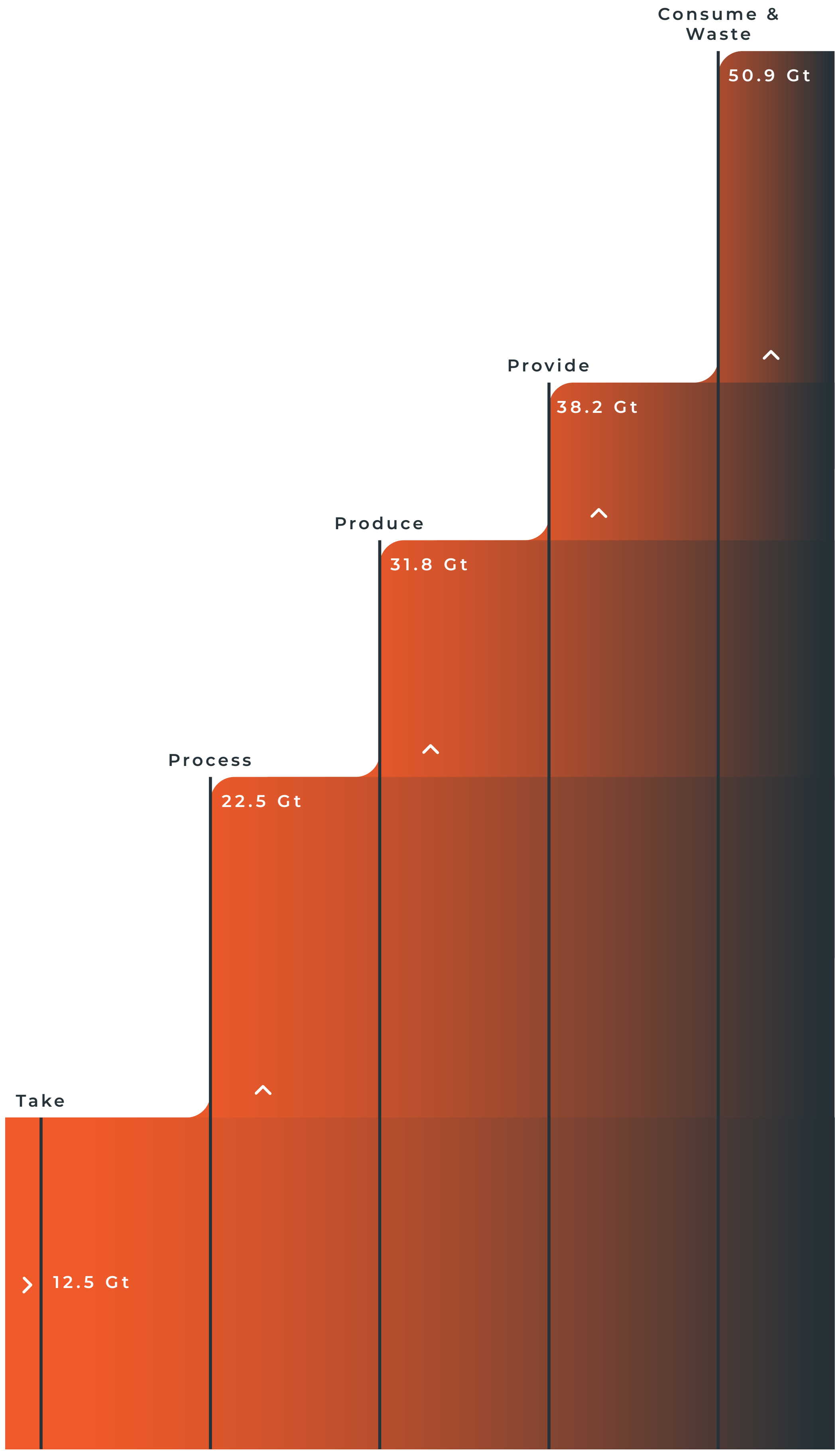


Figure 2. The global carbon emission footprint behind meeting key societal needs, excluding emissions from land use change.[28]

The circular economy is defined along Circle Economy's *Key elements of the circular economy framework*.[29]

CIRCULAR STRATEGIES: KEY ELEMENTS OF THE CIRCULAR ECONOMY

'The circular economy is an economy that is restorative and regenerative by design [and in which] economic activity builds and rebuilds overall system health. The concept recognises the importance of the economy needing to work effectively at all scales—for big and small businesses, for organisations and individuals, globally and locally.'[30]

It assumes dynamic systems, meaning there is no specific end-point, but it is rather a process of transformation. The *Key elements* framework describes eight key fundamentals that give direction to this transformative process. Ultimate aims include slowing (use longer) and narrowing (use less) the flow of resources, closing the loop and switching to regenerative resources and clean energy. The eight elements describe the full breadth of relevant circular strategies and will be used to score the case studies.

International cooperation on climate change mitigation and national climate policies does not yet leverage circular economy strategies to their full potential. Under the Paris Agreement, the years 2020 and 2021 mark an opportunity to strengthen the climate 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—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.

Circular economy strategies can be important additional measures to consider in developing higher emissions reduction targets,[31] since the circular economy—let alone resource efficiency—is hardly considered in existing NDCs. This also places certain types of mitigation measures, which are covered in the NDCs and being acted upon in the GEF target countries, further away from the main scope of this analysis. These are, for example, renewable energy and energy efficiency, as well as forest protection.

Existing mitigation commitments typically rely on increasing renewable energy, improving energy efficiency and avoiding methane and land-use related emissions.[32] Countries can still tap into circular mitigation options in two ways:

1. Where materials and goods are produced domestically, a more circular economy can reduce territorial emissions from virgin material extraction, processing and production; and
2. International cooperation can drive down emissions even further. As the circular economy concept gains traction internationally, there is increasing willingness to reduce the consumption of carbon-intensive goods and materials, even if they were produced abroad. These mitigation options are important, as an estimated 20 to 30% of a nation's carbon footprint stems from the emissions embedded in imported products.[32]

The *Key elements* of a circular economy:

- **Design For the Future:** Adopt a systemic perspective during the design process, to employ the right materials for appropriate lifetime and extended future use.
- **Prioritise Regenerative Resources:** Ensure renewable, reusable, non-toxic resources are utilised as materials and energy in an efficient way.
- **Incorporate Digital Technology:** Track and optimise resource use and strengthen connections between supply-chain actors through digital, online platforms and technologies.
- **Rethink the Business Model:** Consider opportunities to create greater value and align incentives through business models that build on the interaction between products and services.
- **Sustain & Preserve What's Already There:** Maintain, repair and upgrade resources in use to maximise their lifetime and give them a second life through take-back strategies, where applicable.
- **Team Up to Create Joint Value:** Work together throughout the supply chain, internally within organisations and with the public sector to increase transparency and create shared value.
- **Use Waste as a Resource:** Utilise waste streams as a source of secondary resources and recover waste for reuse and recycling.
- **Strengthen and Advance Knowledge:** Develop research, structure knowledge, encourage innovation networks and disseminate findings with integrity.

3.THE MOST PROMISING CIRCULAR MITIGATION INTERVENTIONS

Twelve circular mitigation interventions have been chosen based on their potential to go beyond existing climate action and ability to deliver socio-economic and environmental co-benefits. The mitigation potential could overlap with the potential already targeted in the Intended Nationally Determined Contributions (NDCs) submitted to the United Nations Framework Convention on Climate Change (UNFCCC). These are the first mitigation pledges put forward by Parties to the Paris Agreement but their actual implementation might still require support from the GEF while implementation is also partially conditional upon international support.

Building on earlier research completed for Stanley Foundation,[34] the analysis prioritises interventions that are currently poorly incentivised under the mechanisms for international collaboration included in the Kyoto Protocol, notably the Clean Development Mechanism (CDM). When looking at the emissions reductions certified under the CDM, the vast majority comes from renewable energy, energy efficiency, fuel switching or avoiding the emission of greenhouse gases (GHG) other than CO_2. An estimated 5% stems from interventions in material flows other than fuels or the adoption of circular business models. Examples are closing nutrient cycles with digestion and composting, clinker substitution and recovering caustic soda and the adoption of service models for transport and lighting.[35] In this analysis, we prioritise circular mitigation opportunities that complement those already covered by the CDM.

The selected interventions represent a substantial GHG mitigation potential, which is achieved by altering material flows so that the excessive and unsustainable extraction of primary resources and the disposal of harmful waste are minimised. The positive impact of these interventions beyond climate change mitigation are referred to as co-benefits. These environmental and socio-economic co-benefits are related to biodiversity, chemicals and waste, land degradation and international waters.

The research to identify and elaborate upon the most promising circular mitigation interventions followed five steps:

1. Through a broad literature review, a long-list of circular mitigation opportunities was compiled. The consulted sources included academic literature, the FAO, projects and programmes listed on OnePlanetNetwork and the EU Switch programmes, the results from Project Drawdown and other grey literature.

2. The long-list was shortened by selecting the complementary interventions that take a circular economy approach, or an ability to:

   - Reduce GHG emissions while also reducing the extraction of depletive primary resources like minerals and metals, and reducing the disposal of waste.
   - Complement or scale approaches already widely adopted and applied in international collaboration under the UNFCCC, notably the CDM and Joint Implementation and in the first NDCs submitted by the Parties to the Paris Agreement. Project activities were excluded that only affect fuel use without improving resource use, such as projects that aim to increase the production of renewable energy, improve energy efficiency or reduce methane emissions by flaring.
   - Reduce GHG emissions in the sectors of interest to the GEF, notably: agriculture, urban development and the built environment, forestry, energy and waste management. Such measures must also be relevant to biodiversity, chemicals and waste, climate change, forests, international waters and land degradation.[36]
   - Deliver environmental and socio-economic co-benefits and catalyse transformational change.[37]

3. The remaining interventions were clustered by theme. By identifying synergies across interventions a shortlist of clusters emerged, each containing a set of interventions from the long-list.

4. The clusters identified were verified in an expert panel meeting.

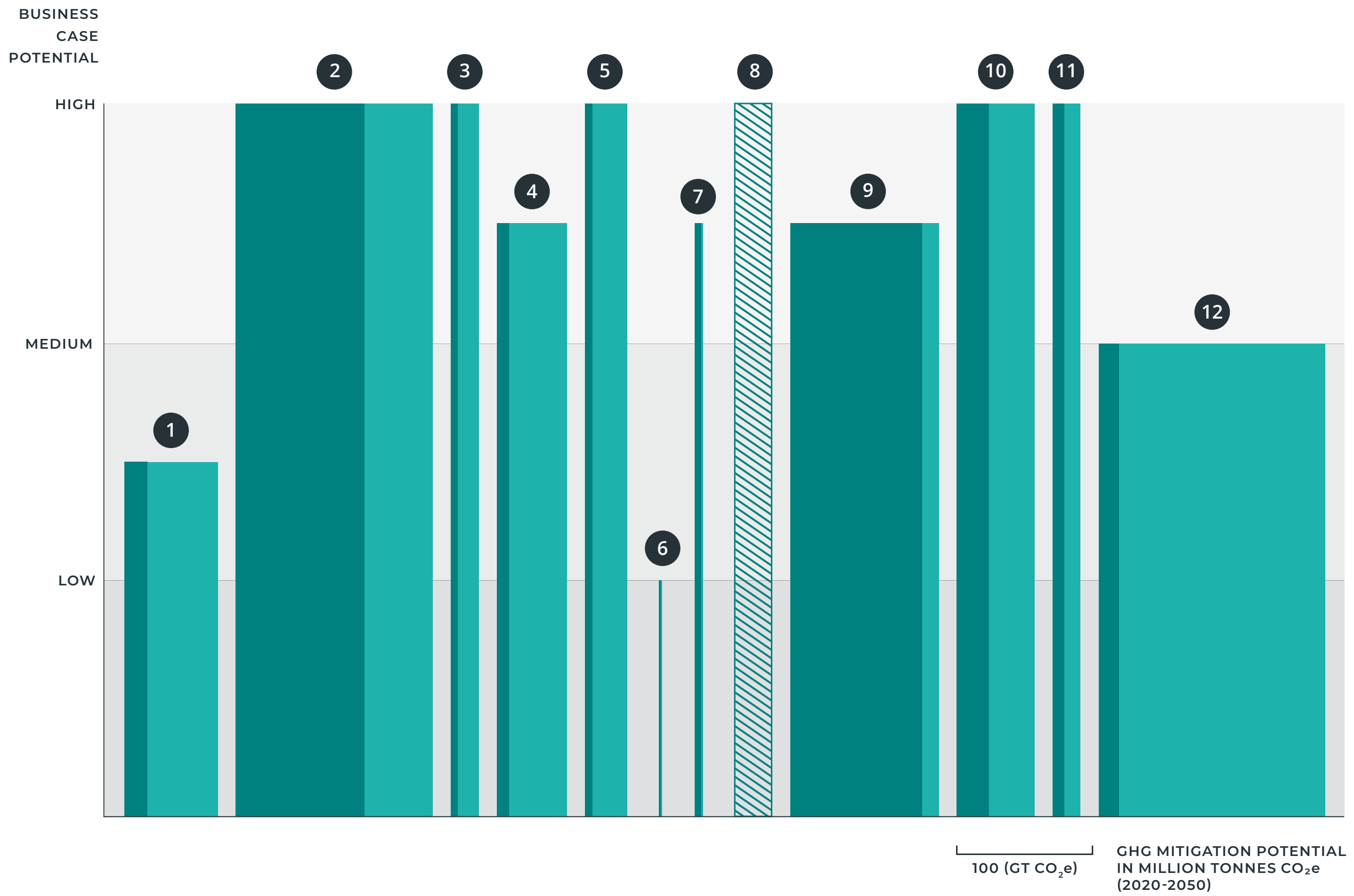
5. For each cluster of interventions, the GHG mitigation potential, business case potential, barriers, enabling conditions and co-benefits were identified through a literature review and 23 expert interviews.

CIRCULAR ECONOMY INTERVENTIONS POTENTIAL

Figure One shows the business case potential and GHG mitigation potential of the interventions proposed. For two of the interventions, literature does not provide a credible estimate of the GHG mitigation potential.

LEGEND

- Lower bound, GHG mitigation potential
- Upper bound, GHG mitigation potential
- Undefined, GHG mitigation potential



INTERVENTIONS, SECTORAL SCOPE AND MITIGATION POTENTIAL

1. **Improved livestock management**
Agriculture; Land use
17—69 Gt CO_2e

2. **Regenerative crop production and agroforestry**
Agriculture; Forestry
95—161 Gt CO_2e

3. **Bioeconomy and bio-based materials**
Forestry; Agriculture; Industry; Construction
5.6—22.5 Gt CO_2e

4. **Reducing food losses from harvest to processing**
Waste management; Agriculture; Food processing; Land use
9—51 Gt CO_2e

5. **Reducing food waste at the retailer and consumer stages**
Waste management; Agriculture; Food processing Land use
5.7—32 Gt CO_2e

6. **Closing the loop on urban organic residues**
Waste management
1.5—2.2 Gt CO_2e

7. **Redesign, reuse, repair, remanufacturing of products and recycling of glass, paper, metals and plastics**
Solid waste management; Industry; Consumer goods and packaging
5—6 Gt CO_2e

8. **Making the renewable energy transition circular**
Energy; Industry; Waste management
Undefined

9. **Eco-innovation in industrial clusters and informal networks**
Heavy industry; Food processing; Manufacturing and assembly; Electricity generation
97—108 Gt CO_2e

10. **Circular design in construction**
Built environment value chain
24—57 Gt CO_2e

11. **Non-motorised and shared transport**
Built environment; Transport
9.9—20 Gt CO_2e

12. **Shifting to healthier and more sustainable diets**
Agriculture; Land use
15—166 Gt CO_2e

THE INTERVENTIONS PROPOSED ARE:

Intervention 1. Improved livestock management

Intervention 2. Regenerative crop production and agroforestry

Intervention 3. Bioeconomy and bio-based materials

Intervention 4. Reducing food losses from harvest to processing

Intervention 5. Reducing food waste at the retailer and consumer stages

Intervention 6. Closing the loop on urban organic resides

Intervention 7. Redesign, reuse, repair, remanufacture of products and recycling of glass, paper, metals and plastics

Intervention 8. Making the renewable energy transition circular

Intervention 9. Eco-innovation in industrial clusters and informal networks

Intervention 10. Circular design in construction

Intervention 11. Non-motorised and shared transport

Intervention 12. Shifting to healthier and more sustainable diets

Figure 1. Business case and GHG mitigation potential

INTERVENTION 1. IMPROVED LIVESTOCK MANAGEMENT

Reduce emissions from livestock through productivity improvements, improve manure management and introduce anaerobic digestion of manure.

Sectoral scope	Agriculture; Land use
Synergy with GEF areas of operation	Biodiversity; Chemicals and waste; Climate change; Food systems, land use, and Restoration
IPCC categories targeted	3A Livestock: Reduced methane emissions from enteric fermentation and manure management 3C Aggregate sources and non-CO_2 emissions sources on land: Reduced nitrous oxide emissions from urea and manure application

1A. STRATEGY DESCRIPTION

This strategy aims to reduce emissions from livestock. As a proxy, the carbon intensity[38] of meat production in Latin American, African and South/Southeast Asian countries often exceeds 80 tonnes CO_2 equivalents (CO_2e) per tonne of meat produced. This is approximately twice as high as in North America and Europe.[39]

For many of the GEF recipient countries, agriculture is also the prime source of green-house gas (GHG) emissions.[40] The non-Annex 1 countries[41] under the UNFCCC are mostly low- and middle-income countries. With the exception of a few economies in transition, the Annex 1 country list overlaps with the GEF recipient countries. In Annex 1 countries, livestock emissions account for 65% of total GHG emissions from agriculture when considering emissions from enteric fermentation, manure application and manure management.[42] Out of all global GHG emissions from these activities, 69% are from non-Annex 1 countries under the UNFCCC.[43]

The most prominent source of GHG emissions from livestock stems from enteric fermentation, which is difficult to abate without reducing herd size. This is often not an option since livestock are an important source of income for smallholder farmers, providing livelihood, food and nutrition security to almost 1.3 billion people globally.[44] Next to this, livestock plays an important role in a circular food system.[45] Livestock can, for example, **use waste as a resource** by converting residual flows or crops unsuitable for human consumption, consuming grass and herbs from pastures in areas unsuitable for growing food and providing manure to enhance soil quality. The latter is important in countries with low soil fertility[46 47 48] and can keep GHG emissions from synthetic fertiliser production and application low.

Livestock can also provide energy, through the processing of manure in small-scale anaerobic digesters. Anaerobic digestion produces biogas, which can be used as an alternative energy source to fossil fuels or firewood, the extraction of which contributes to forest degradation.[49] These approaches, in turn, **prioritise regenerative resources**.

Further opportunities to reduce GHG emissions from livestock include increasing feed quality and overall productivity, by **designing for the future**.[50] For example, managed grazing, which refers to achieving an optimal balance in how long an animal grazes on a specific grassland and how long the land needs to rest before the animals return. Managed grazing aims to prevent over- and undergrazing and the negative impacts of each, namely a decline in soil health and carbon losses. Feed and dietary additives may also be used, which increase productivity and reduce emissions from enteric fermentation. This could include prioritising locally produced feed, avoiding over- or underfeeding and storing feed or silage for use during the dry seasons to maintain productivity.

Selective breeding, which prioritises breeds with higher productivity or reduced emissions from enteric fermentation, may also be considered. This design approach to circular livestock has been successfully applied in Kenya, where livestock management, food security and resilience were improved through veterinary services.[51 52] Additionally, improved herd management, which includes decreasing mortality, improving sanitary conditions, animal health, herd renewal and diversifying animal species could be an important avenue in designing for the future. Finally, improved manure management, which includes manipulating bedding and storage conditions, such as reducing storage time or removing bedding from manure by using solids-liquid separators,[53] should be considered.

1B. GREENHOUSE GAS MITIGATION POTENTIAL

17 to 69 billion tonnes CO_2e between 2020 and 2050. This figure is based on global mitigation potential for improved livestock management (6-72 billion tonnes CO_2e),[54] managed grazing (16-26 billion tonnes CO_2e)[55] and the implementation of small-scale anaerobic digesters for manure (1.9 billion tonnes CO_2e).[56]

The global figures for GHG mitigation potential in the livestock sector are derived from the IPCC and Project Drawdown and have been corrected to cover only the GEF countries of operation. For this correction, the country grouping of non-Annex 1 countries under the UNFCCC[57] has been used as a proxy for the GEF countries of operation. This proxy is imperfect since the non-Annex 1 countries exclude all EU Member States and several economies in transition. According to FAOSTAT, 69% of global livestock-related GHG emissions are from non-Annex-1 countries under the UNFCCC.

This estimate is conservative as it does not account for the higher carbon intensity of meat production in non-Annex 1 countries. The mitigation potential of aligning production methods with those in Annex 1 countries[58] has deliberately not been considered. This allows farmers to maintain free roam livestock practices, even if intensified livestock systems with large-scale manure digesters can have lower GHG per tonne of meat or dairy produced.

On an annual basis, the emissions reduction potential would be between 0.6 and 0.7 billion tonnes CO_2e.

1C. BUSINESS CASE POTENTIAL

Low/medium. Investments in low-carbon and resource-efficient livestock management often rely on subsidies or carbon incentives to become attractive for smallholder farmers.

On a global scale, the total investment in improved feeding and grazing[59] and anaerobic digesters at farm[60] and smallholder level[61] requires an investment of approximately |US$267 billion, while the net savings in operational expenditures as a result of the investment amount to US$898 billion between 2020 and 2050. Even though the investment pays off in the long-run, pay-back periods of over nine years, when dividing the investment through the savings over 30 years, are too long.

The business case for biogas development by smallholders differs: it is determined by fuel and time savings and income generated by applying the slurry from the digester as fertiliser. The majority of biogas users report money and time savings as a major benefit of the technology, whereby the financial benefits of the bioslurry can be more important to the farm operations than the biogas. Estimates suggest that households can recover their investment costs in two to three years.[62] Because of this estimated payback, the business case potential for the range of measures proposed under this intervention is categorised as low to medium.

1D. CO-BENEFITS

In addition to climate change mitigation, **climate resilience** is another important benefit. More productive livestock systems and specific measures, such as improving animal feed storage to ensure its availability throughout dry periods[63] or breeding better-adapted livestock, all serve to improve **food productivity and security**,[64 65] and as a result, increase the food system's resilience to climate change.[66] Globally, increased food productivity has prevented up to 15.14 million square kilometres of land from being exploited or degraded.[67]

Improved manure management also increases the contribution that a low-carbon and resource-efficient livestock system can make in avoiding **land degradation**. Additionally, the production of biogas, a renewable energy source, can help **reduce energy deficits** in rural areas,[68] as well as **deforestation and forest degradation**, by reducing firewood extraction below levels which exceed the annual increment. Biogas production has the potential to reduce deforestation by 4 to 26% in 2030.[69] In other countries, it may help reduce the use of kerosene and liquified petroleum gas for cooking.

Claims that livestock can contribute to **bio-diversity** and **carbon sequestration** in soils are true only under certain stocking and grazing management practices.[70 71 72]

Socio-economic benefits include **increased farmer incomes** from productivity gains. Effective manure application can increase crop yields in mixed farm systems. The improved preservation of feed helps retain productivity in dry seasons, which allows farmers to make better margins, as dairy prices tend to increase in dry seasons. Improved livestock productivity can also reduce **desertification and land degradation**, for example through reduced stocking densities—[73] the number of animals kept on a given area.

Connecting toilets to anaerobic digesters also helps to improve **sanitary, health and environmental conditions**,[74] as 80% of all deaths in developing countries are related to water- and excreta-related diseases.[75]

Using biogas for cooking instead of firewood has substantial **health benefits** from improvements in indoor air quality, which may be of the order of 66 to 99% and could bring respiratory and cardiovascular health benefits: a 20 to 25% reduction in risk of a wide range of diseases.[76] Indoor air pollution is an insidious killer according to the WHO, with most casualties occurring in Africa and Southeast Asia.[77]

Using biogas for cooking also saves farmers' valuable time. As women are primarily responsible for the collection of firewood in many countries,[78] the shift to biogas provides an additional **gender benefit**, as women can regain up to 50% of their time.[79] Where there is excess biogas available, it could also be used to run irrigation systems, instead of solar panels or diesel engines. Reliable irrigation can further improve the **productivity** of crops.[80] Finally, the digester sludge is a safe organic fertiliser, which can reduce expenditures on synthetic fertilisers and the emissions associated with their production.

1E. BARRIERS

Economic and financial. Smallholder farmers—concerned with the immediate survival of their business—can be risk-averse. They also lack the means and access to capital to make investments, and banks often require smallholders to be organised in a cooperative to reduce lending risks. Larger commercial farms may require additional incentives to switch to low-carbon livestock practices because of the initial level of investment required.

Limited access to financial credit, in part due to a lack of collateral, is an additional barrier to improved manure management.[81] Next to capital investments, farmers also need to invest in labour and knowledge, which increases short-term production costs.[82] Overall, shortage of labour was considered an important barrier by farmers.[83]

For the implementation of smallholder biogas systems, further economic barriers apply, like the high upfront investment[84] and maintenance costs,and competition with firewood which is often freely available.[85]

Finally, financial incentives provided are often targeted at the construction of anaerobic digesters and sometimes at purchasing synthetic fertilisers. There are little incentives for farmers to improve their manure management and livestock productivity.[86]

Technological. The interventions proposed are not complex but some of the technologies for improved feed storage and large-scale anaerobic digestion require bulk transport of manure, which is not always available in rural areas due to limited access to credit. The bulky nature of manure also makes it more labour-intensive to manage, which can lead farmers to prefer synthetic fertilisers.[87] At a smallholder level, investments in biogas systems are hampered by the lack of adequate feedstock and water, poor technical expertise and poor design of the digestion systems.[88]

Legal, regulatory and institutional. A lack of policies, regulatory frameworks and standards that encourage private investment in digesters of high quality create institutional barriers for smallholders. Where there is legislation in place, the focus is often on energy production and addressing public health issues. The fertiliser and food security value of manure is seldom a driver for policy.[89]

Cultural. In some societies there are cultural barriers to using manure as a fertiliser in food production systems. In addition, farmers are more risk averse towards livestock management practices they are unfamiliar with.[90] Cultural barriers for the adoption of biogas systems include a preference for traditional cooking practices and a gender barrier. While women are the primary beneficiary, men are more likely to make the investment choice.[91] Finally, a lack of awareness and knowledge of the value of manure as fertiliser does not foster changes in manure management.[92]

1F. ENABLING CONDITIONS

Technologies can be subsidised or soft loans provided to overcome financial barriers, but also to bridge the long payback of some of the investment options. Microfinance institutions can play an important role here. Such financial incentives can compensate for the lack of pricing of negative externalities, for example, related to the extraction of firewood which could cause forest degradation, or methane emissions from livestock systems. To create a sense of ownership over the technology provided, it is important that farmers co-invest.

Technical barriers can be overcome with adequate training and sufficient stakeholder engagement in the design of interventions. Solutions in livestock systems need to be tailored to specific local conditions.

The development of explicit organisations that promote biogas, support with addressing legal and financial barriers, provide up-to-date information and support biogas research and development can help overcome knowledge and awareness barriers.[93]

Cultural barriers can be overcome with extension services, explaining the value of nutrient cycling in mixed farms and altering negative perceptions of manure handling and application.[94]

CASE STUDY EXAMPLE: KENYA BIOGAS PROGRAM DEVELOPING A SUSTAINABLE, DOMESTIC BIODIGESTER SECTOR IN KENYA

The Kenya Biogas Program is a public-private partnership between development partners Hivos, SNV (Netherlands Development Organization) and the Directorate General for International Cooperation (DGIS) of the Dutch Ministry of Foreign Affairs and the Africa Biogas Partnership Programme (ABBP) in Kenya. Its objective was to develop a commercially viable and sustainable domestic bio-digester sector in Kenya, using revenue from the sale of carbon credits to subsidise the programme.[95] For those who own dairy cattle, just two cows can provide sufficient manure for a biogas plant that provides enough gas for cooking.[96]

Over 17,000 bio-digesters were installed across Kenya between 2009 and 2020, serving over 100,000 beneficiaries. This programme helped reduce emissions by 365,200 tonnes CO_2e and prevented the extraction of 223,000 tonnes of wood. The emissions reductions from the application of bio-digester sludge as fertiliser have not been included in the GHG mitigation estimate. The programme also created job opportunities: it trained at least 577 masons to build biogas domes, 82 of which operate as business entities and 240 of which as sole proprietors.[97]

The Kenya Biogas Program adopted a specific marketing model using ‘Biogas Marketing Hubs’. This approach relies on concentrating bio-digester information, training, sales, extension and marketing efforts on beneficiaries that have common interests; such as dairy, coffee and tea farmer Cooperatives.

Beneficiaries of the programme confirmed that the use of biogas enhanced their lives, improved indoor air quality, lowered expenditures on synthetic fertiliser and increased yields. What’s more, the lowered expenditures resulted in more farmers’ children attending school[98] ; and, women were empowered as a result, as they were previously responsible for the time-consuming collection of firewood. Finally, the programme resulted in significantly decreased firewood use: in Kenya, households with bio-digesters use 2.1 to 3.3 tonnes less wood per year than households without.[99]

The programme also overcame a number of barriers. To address increasing abandonment rates, it launched customer service centres and repair campaigns in 2016, decreasing technical failures.[100] It also worked to improve the connection with target customers by adjusting the focus of marketing campaigns from the benefits of biogas to the benefits of the digester sludge for crop production. However, to protect the interests of the biogas sector in the long run, the programme launched an Association of Biogas Contractors of Kenya (ABC-K) and Association of Biogas Sector of Kenya (ABSK). The membership of both organisations continued to safeguard the interest of the biogas sector, also beyond the closure of the programme. To secure access to finance for biogas plants under attractive terms, the programme has initiated various credit partnerships with financial institutions. To secure access to finance for biogas plants under attractive terms, the programme has initiated various credit partnerships with financial institutions.[101]

INTERVENTION 2. REGENERATIVE CROP PRODUCTION AND AGROFORESTRY

Invest in cropland management practices that regenerate soil health, and increase biodiversity and carbon sequestration, including the use of agroforestry and mixed cropping.

THIS INTERVENTION IN CONTEXT

One of the aspects of this intervention is to utilise foodlost and organic waste as a resource on the farm as compost. For a discussion on avoiding post-harvest losses altogether, see **Intervention four**. For a discussion on avoiding food waste—or unused food at the retail and consumption levels—see **Intervention five**. Where waste is unavoidable and stems from urban areas, it is used as a resource through the solutions proposed in **Intervention six**.

Sectoral scope	Agriculture; Forestry
Synergy with GEF areas of operation	Biodiversity; Climate change; International waters; Sustainable forest management; Chemicals and waste
IPCC categories targeted	3B Land; 3C Aggregate sources and non-CO_2 emissions sources on land; 2B Chemical industry

REGENERATIVE CROP PRODUCTION

Circular, regenerative farming makes optimal use of crops and crop residues, replenishes soil health instead of clearing more land for agricultural use and reduces synthetic fertiliser use and associated emissions.

Follow the green resource and emission flows to understand the resource use and its impact on emissions in a circular value chain, compared to a linear value chain, highlighted in red.

Note that the flows in this graph are indicative only and aim to illustrate extreme opposite circular and linear value chain.

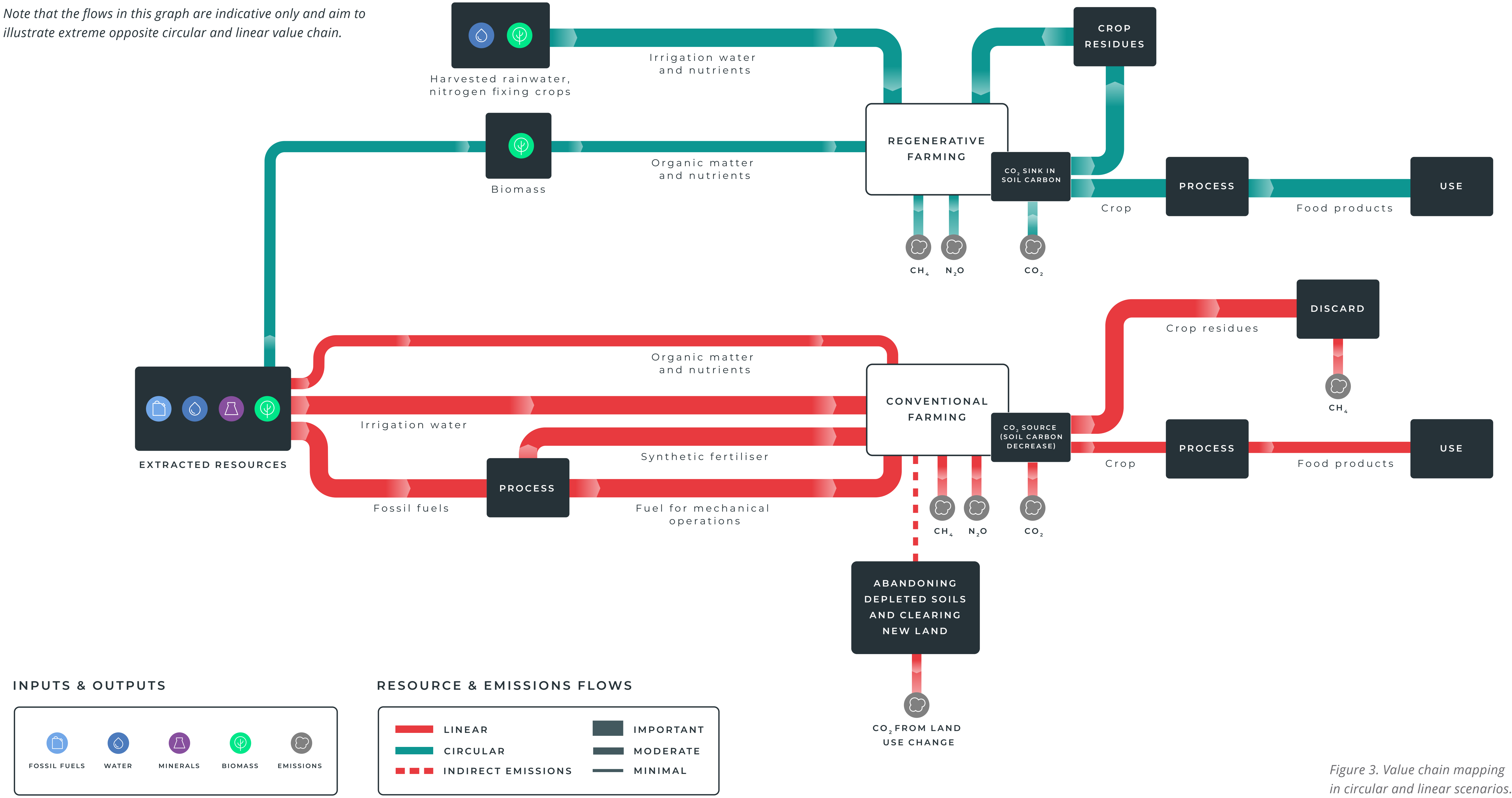


Figure 3. Value chain mapping in circular and linear scenarios.

2A. STRATEGY DESCRIPTION

Regenerative crop production refers to agricultural practices that invest in soil health and fertility and conserve overall biodiversity on croplands. These practices also improve soil's water retention and provide natural ways to control weeds, pests and diseases. As a result, they reduce the need for chemical fertilisers and pesticides and mechanical operations like ploughing, weeding and irrigation, which often involve fossil fuels. Synthetic fertiliser use alone is responsible for 7 to 26% of agricultural emissions in South Asia, Sub-Saharan Africa, North Africa, the Middle East and Latin America combined, even without accounting for the emissions associated with their production.[102]

Regenerative crop production proposes a range of measures that partly rely on using **organic waste as a resource**, by making better use of organic agricultural residues, and **prioritising regenerative resources** since it steers away from fossil fuel use in mechanical operations. It also relies on efforts to sustain and **preserve what's already made**, which relates to the preservation, conservation and enrichment of biological assets such as soil, land and forests. As such, it relies on and overlaps with principles of organic farming, conservation agriculture, agroecology and climate-smart agriculture.

Regenerative crop production also includes agroforestry and community-managed forests, whereby forest ecosystems are protected and managed such that different layers of vegetation both sequester carbon and provide food. Agroforestry can also provide food with lower fossil fuel and chemical inputs.

Practices included under the umbrella terms of regenerative crop production and agroforestry include:

- No-till agriculture to preserve soil organic carbon and reduce GHG emissions from the soil.
- Improved crop varieties, crop rotation, the use of nitrogen fixing crops when the land is fallow,[103] cover crops to reduce soil erosion, control weeds and improve water retention.[104]
- Improved water management including drainage of waterlogged mineral soils and irrigation of crops in arid or semi-arid conditions.
- Improved rice management, including water management such as mid-season drainage and improved fertilisation and residue management in paddy rice systems.
- Increasing biodiversity with intercropping, agroforestry and protecting communities' forest tenure, thereby preserving the eco-system services these forests provide.[105][106] This includes practices like using trees and shrubs to provide fodder and control erosion, while branches can be used for fuel or food stakes for tomatoes or climbing beans.[107]
- Biochar application. Biochar is a solid product from the pyrolysis of wood. When applied, it increases the water-holding capacity of the soil and may provide better access to water and nutrients for vegetation. Biochar application is most effective in tropical regions, but its positive impacts could be cushioned by additional pressure on land use if large quantities of biomass are required as feedstock for biochar production.[108]

2B. GREENHOUSE GAS MITIGATION POTENTIAL

95 to 161 billion tonnes CO_2e between 2020 and 2050. Assuming wide-scale adoption alongside forest, coastland, wetland and grassland protection efforts, regenerative agriculture and agroforestry have the potential to reduce global GHG emissions by 95 to 161 billion tonnes CO_2e between 2020 and 2050. This figure includes global GHG mitigation estimates from Project Drawdown that relate to conservation agriculture (9-13 billion tonnes) and combined agricultural and forestry activities. These are: regenerative annual cropping (15-22 billion tonnes), nutrient management (2-12 billion tonnes), perennial staple crops (15-31 billion tonnes), abandoned farmland restoration (12-20 billion tonnes), silvopasture (27-42 billion tonnes), multistrata agroforestry (11-20 billion tonnes), tree intercropping (15-24 billion tonnes), Indigenous peoples' forest tenure (9-13 billion tonnes) and improved rice production (9-14 billion tonnes) with intensification (3-4 billion tonnes).[109]

The global figures for GHG mitigation potential through regenerative agriculture and agroforestry from the IPCC and Project Drawdown have been corrected to cover only the GEF countries of operation. For this correction the country grouping of non-Annex 1 countries under the UNFCCC[110] has been used as a proxy for the GEF countries of operation. As in Intervention one, this proxy has its limitations.[111] This global figure of 128.04 to 217.43 billion tonnes CO_2e is confirmed by the IPCC Special Report on Climate Change and Land, which quantified the mitigation potential of improved cropland management, agroforestry and increased soil organic carbon alone at 57 to 498 billion tonnes CO_2e between 2020 and 2050.[112]

The main GHG mitigation levers are land-use change to productive ecosystems with a higher equilibrium soil carbon level and forest carbon stock, and reducing emissions from the production and application of chemicals as well as from mechanical farming operations.

Implemented at scale, these practices can increase food productivity and consequently reduce the need for converting more land for agriculture. They also reduce emissions by decreasing the need for chemical fertilisers and mechanical farming operations, and through agroforestry, contribute to increasing forest carbon stocks.[114] The effectiveness of regenerative farming practices in increasing carbon content in soils, however, is still a topic of debate, partly originating from different definitions of regenerative agriculture and accounting methodologies.[115]

2C. BUSINESS CASE POTENTIAL

High. At a global level, investments into the proposed regenerative agriculture and agroforestry mitigation options would require an upfront investment of around US$900 billion, while net operational savings as a result of the investment are around US$9,000 billion up to 2050.[116] This implies that the simple payback, not considering interest rates if loan financing is required, is around three years on average across the proposed interventions.

The interviews conducted confirmed that shifting to regenerative agriculture is economically beneficial in low- and middle-income countries, although the interviewees referred to a longer time horizon than reflected in the figures from Project Drawdown.[117]

2D. CO-BENEFITS

Climate change mitigation is an important benefit of this intervention, but the underlying strategies proposed also contribute to improving the **climate resilience** of food production systems, as higher soil carbon levels, cover crops and agroforestry all improve water retention.[118]

Further co-benefits include increased **biodiversity**, both above ground and in the soil, as soil life improves when monocropping is reduced.[119] Additionally, farms practising regenerative agriculture can serve as corridors for wildlife by connecting nature reserves and green areas. Having a more biodiverse food system also provides variety in the food products harvested, while higher soil fertility improves the nutritional value of the products. This supports a **healthier** diet.

Regenerative agricultural systems also require fewer chemical inputs, further decreasing **chemicals and waste**, while investing in soil quality and providing soil cover helps prevent **land degradation**.[120] Reduced application of agrochemicals also provides **health benefits**. There are concerns that chemicals banned in other countries are still applied in certain countries, like Kenya, despite the adverse health effects of chemical residues on crops.[121]

In terms of socio-economic impacts, the business case indicates that this intervention could improve yields. In many areas, trees are financially important. Irvingia gabonensis, for example, grown in Nigeria, Cameroon and Gabon, bears nuts and flowers with significance in national markets and for exports.[122] Furthermore, regenerative agriculture values the **traditional knowledge** of farmers and incorporates this knowledge into farm-level innovation. Along the same lines, preserving landscapes with mixed vegetation has an aesthetic value[123] and supports community coherence where trees like the baobab are used as meeting places.[124]

2E. BARRIERS

Economic and financial. Prioritising regenerative agriculture and agroforestry systems is financially feasible, as the long-term benefits far outweigh the investments. However, farmers often lack access to the financial means needed to make this investment. Grants offered to farmers often lack the long-term perspective required to make such a transition work.

For agroforestry, in particular, financing has put little emphasis on investing in seed quality. Benevolent NGOs that hand out seeds and seedlings for free inadvertently diminish efforts to build a private market for these. Instead, private seed and seedling companies should be supported.

Legal, regulatory and institutional. There is little political priority attached to regenerative farming and agroforestry. While there are often logging bans in place to prevent deforestation, enforcement is weak, and activities continue to drive deforestation and soil depletion on the ground. Policy loopholes allow for monoculture plantations like rubber farms, for example, to be counted towards reforestation quotas. Additionally, political priorities may change frequently, resulting in uncertainty.

Another legal issue is that policies aiming to prevent people from cutting down their trees also discourages them from planting them for future use. For example, policies in Niger,[126] which allowed people to use their trees, led to a huge increase in tree cover. Land tenure issues may also act as a barrier: if farmers are concerned about paying the following years' rent, they will be discouraged from making long-term investments in regenerative practices.

Technological. The technologies available today are focussed on monocropping, rather than implementing regenerative farming at scale. The knowledge and experience to do so are often lacking, as it requires breaking down complex farming systems into educational packages which potential practitioners can understand. Research efforts, capacity building, financing and pilot projects should go hand-in-hand and all relevant stakeholders should be involved.[127]

Cultural. Tied to a lack of access to financing and long-term land use perspective is an overall short-term planning perspective. This can be aggravated by volatile political circumstances which give way to uncertainty.

2F.ENABLING CONDITIONS

There is currently a lot of momentum[128] for regenerative agriculture and agroforestry in the private sector, with substantial investments being made around the world by corporations such as Nestlé,[129] Danone[130] and General Mills[131] in the last year alone. Still, significant potential remains.

Regenerative farming and agroforestry investments require long-term loans, which must also consider the variation in annual yields and related revenues. Following a common practice in microfinance lending—grouping smallholders in a single loan package—can reduce the overall risk of defaults.[132]

Financial returns can be further increased by coupling the transition to regenerative agriculture and agroforestry with efforts to create a market for the associated products and input. For example, by creating a market for agroforestry products or products with a regional organic certification, or developing the supply of tree seedlings for agroforestry.

Small-scale pilots or demonstration farms can build proof and showcase the benefits of the technologies and practices applied in particular geographical contexts. Furthermore, trainings can help overcome the relatively short-term planning horizon of smallholders, while the financial and capacity support provided by the programme should have a similarly long-term scope.

CASE STUDY EXAMPLE: UNION OF LAND WORKERS TRANSFORMING ARGENTINA'S AGRICULTURAL LANDSCAPE THROUGH AGROECOLOGY

The Union of Land Workers (UTT) works to improve food sovereignty and promote agroecology by bringing together and empowering farming families in Argentina.

'Agroecology' is a set of principles and agricultural practices that seeks to promote both a circular and solidarity economy—one that 'prioritises local markets and supports local economic development through virtuous cycles'.[133] As such, agroecology promotes resource efficiency and closed-loop recycling; reduction of inputs such as pesticides, herbicides or synthetic fertilisers and biodiversity conservation as much as social values, fairness or the co-creation of knowledge.[134]

The activities of UTT are an interesting example as they target a range of barriers in parallel, while involving a broad range of stakeholders. Their activities range from advocating for improved legislation and secure access to land for farmers, the provision of micro and soft loan schemes for smallholders, to training and capacity-building.

UTT has reached 250 families producing agro-ecologically across various provinces of Argentina, with a farmer-to-farmer training process. According to UTT, they have converted 300 hectares of land to agro-ecological production while increasing yields by 20%, saving 80% in farm expenditures and doubling revenues by direct sales through UTT sales channels. The food products have higher nutritional value and contain no traces of agro-chemicals while matching the market price of conventionally produced products. The union negotiates with local governments to gain access to abandoned or degraded farmland. Once access is granted, they grant unemployed workers access to the land and train them in food production with regenerative agriculture and agroecology principles. These workers obtain soft loans to purchase the land and can sell their products through UTT sales channels. Training is provided by farm technicians and farmers.[135]

INTERVENTION 3. BIOECONOMY AND BIO-BASED MATERIALS

Scale the mechanical and chemical processing of agricultural and forest residues to produce bio-based materials for construction (and other industries).

Sectoral scope	Forestry; Agriculture; Industry; Construction
Synergy with GEF areas of operation	Food systems, land use and reforestation; Chemicals and waste; Sustainable forest management
IPCC categories targeted	2 Industrial processes and product use 3C1 Biomass burning 3D1 Harvested wood products 4A Solid waste disposal 4C Incineration and open burning of waste

3A. STRATEGY DESCRIPTION

Deploying bio-based materials is about **prioritising regenerative resources**. When targeting the substitution of carbon-intensive materials with bio-based alternatives, the bioeconomy has significant GHG mitigation potential. The focus of this intervention is on the use of bio-based materials. Biomass as a fuel source is not included as it is already covered at large in the CDM and thereby also well on the radar of policymakers and businesses.[136]

This intervention reduces GHG emissions along value chains. This means that by **designing for the future** by switching to regenerative materials in the production of goods or the construction of buildings and infrastructure, emissions from industries that supply the displaced carbon-intensive materials can be reduced.

It is crucial that the sourcing of bio-based materials does not compete with food production or drive other adverse impacts like biodiversity loss, soil depletion or deforestation. **Using waste as a resource** reduces competition with other land uses; sourcing bio-based materials from waste streams from the production of food and forestry products, for example (see also Interventions four and five). In addition, biomass could be sourced from sustainable forest plantations or algae farms[137] or use mycelium as an alternative resource to produce leather-like material, without resource-intensive animal farming, packaging foam or even bricks.[138]

Bio-based materials are often viewed as crucial for halting environmental and marine pollution caused by excessive consumption of plastic. However, only biodegradable or compostable bio-based materials can effectively reduce marine pollution. These materials must also decompose in lower marine temperatures or be properly disposed of in industrial composting facilities.[139] Bio-based materials thereby predominantly target sourcing. Addressing the waste issue requires further investment in the development and end-of-life collection and treatment of bio-based materials.

3B. GREENHOUSE GAS MITIGATION POTENTIAL

5.6 to 22.5 billion tonnes CO_2e between 2020 and 2050. According to the IPCC, the total reduction of GHG emissions from the use of wood and agricultural biomass for building, textiles and other applications can account for between 7.5 and 30 billion tonnes CO_2e between 2020 and 2050. On an annual basis, that is 0.25 to 1 billion tonnes CO_2e per year.[140] These figures have been adjusted for the share of industrial GHG emissions that stem from non-OECD countries. This share is 75%.[141]

As an example of the measures included in this estimate, in the construction sector, replacing conventional construction materials with industrial wood products like cross laminated timber reduces the embodied carbon in materials and structures from approximately 300 to 550 kilograms CO_2 per square metre, and structures can sequester 0.8 to 0.9 tonnes CO_2 per cubic metre.[142] Emissions from cement production alone are responsible for 4% of global GHG emissions from fossil fuel use.[143]

3C. BUSINESS CASE POTENTIAL

High. Building with cross-laminated timber is cost-competitive—[144] only a few percent higher than using reinforced concrete and can significantly reduce construction time. When combined with offsite construction, buildings can be erected in a timeframe of a few months,[145] also because the lighter construction materials reduces the requirements for the foundation of the building. Shortening the time in which loan interests and land tenure have to be paid without having a functional building in place has a positive effect on the internal rate of return.[146]

The advantages of using prefabricated cross-laminated timber[147] panels are also referenced for bamboo construction.[148] Next to delivering more sustainable buildings, the modular, rapid and safe on-site assembly reduces costs, construction activity impacts and waste.

Bio-based plastics and packaging can improve resource security and reduce exposure to price volatility, or new regulations that address the negative externalities of conventional materials. The Centre for Economics and Business Research (CEBR) estimates that the bio-plastics sector has the potential to meet the United Kingdom's economic goals by unlocking job creation potential along the value chain, increase the direct employment contribution from 1,000 to 14,400 full-time equivalents, and increase gross value added from £50.5 million (US$ 68.9 million) to approximately £764.6 million (US$ 1042,75 million).[149]

3D. CO-BENEFITS

The construction sector is a major source of GHG emissions, mainly due to its use of carbon-intensive materials like concrete and steel.[150 151 152] Where sustainably sourced bio-based products are used, the sector and industries providing construction materials can become a **net carbon sink**,[153 254] rather than a major source. In fact, the use of carbon-sequestering wood in construction is a far more effective way to mitigate climate change than the use of wood as a fuel.[155]

When applying modular design and design for disassembly, wood products **can easily be recovered and reused** at the end of the building's functional lifetime. The reusability is affected by how the timber has been treated and how the building has been constructed.[154]

Bamboo is a renewable material, which grows fast and can be cultivated in plantations in many of the GEF countries of operation. Moreover, bamboo has been found to be suitable for land restoration in degraded ecosystems.[157] However, it is important that there are strong guarantees in place that plantations do not contribute to deforestation or compete with land use for food production.

The use of natural construction materials has physiological and psychological benefits to the **health and wellbeing** of the users of a building, such as decreasing stress levels or improving an individual's emotional state.[158] In urban environments, the reduced construction time has financial benefits but also reduces noise pollution for nearby residents. Additionally, the buildings are lightweight and more **resilient** to calamities like fire and earthquakes.[159]

The substitution of fossil fuel-based materials with bio-based materials has purposes outside of the construction sector. However, some notes to consider:

- Such substitution decouples non-renewable fossil resources that contribute to GHG emissions during combustion,
- Some bio-based materials can be composted after their use, closing the nutrient cycle. However, composting facilities are not always available.
- If bio-based materials are compostable, they can help **protect marine and terrestrial ecosystems** by avoiding persistent litter and environmental pollution caused by fossil fuel-based materials like plastics. Marine plastic debris has been proven to lead to the death of wildlife, hence irreversibly reducing **biodiversity**.[160]

Overall, the bioeconomy holds the potential to preserve biodiversity, generate higher revenues for farmers and foresters, provide products with a lower carbon footprint and biodegrade and enrich rather than pollute ecosystems.[161]

3E. BARRIERS

Economic and financial. The cost of investing in the industrial capacity to produce bio-based materials might be prohibitive for low- to middle-income countries.

Even though there are case studies where Cross-Laminated Timber (CLT) has proven to reduce investment costs compared to other structural materials,[162] the level of cost-competitiveness that CLT has in new constructions varies depending on the type and complexity of the project. This is shown by the fact that other studies point towards the opposite direction. Fanella (2018) study states that the use of traditional structural materials in new constructions, such as reinforced concrete, have proven to be more cost-competitive than using Cross-Laminated Timber (CLT).[163] Therefore, we can conclude that the financial feasibility and cost-competitiveness of CLT compared to other structural materials needs further exploration to incentivise an increasing uptake of this biobased materials.

Next to this, the uptake of bio-based packaging remains low. Despite research, development and investment—including from the EU—into bioeconomic material solutions, bio-based plastics represented only between 0.5 and 1% of EU annual plastic consumption in 2017.[164] The reason is mostly financial: a lack of economies of scale and not pricing the externalities of plastic pollution and fossil fuel use, or even considering the end-of-life impact in Life Cycle Assessments. Bio-based packaging is three to five times more expensive than fossil-based packaging materials.[165]

Legal, regulatory and institutional. In some countries, building codes do not allow for the application of wood at scale. [166 167 168]

Several of the GEF target countries suffer from deforestation. The raw materials for bio-based materials should be responsibly sourced. While in the Northern Hemisphere, forest cover is increasing, in the Southern Hemisphere it is not. Legal and institutional safeguards need to be implemented to avoid further deforestation.

Strict regulations are in place for all materials used in food packaging, in which case biomaterials are expected to perform equally or better than fossil-based plastics. Therefore, documentation is required on the presence of inorganic contaminants such as heavy metals, persistent organic contaminants and their capacity to transfer from bio-based packaging into food.[170] Allergenicity of bio-based materials might also become an issue in some applications.

Technological. Biomass is often a seasonal product while fossil fuels are not. Biomass production is also affected by climate change. This makes the sustainable mobilisation of biomass more challenging. In addition, poor data on biomass availability and accessibility, for example in Africa, hinders businesses in setting up bio-based industries.[171]

While bioplastics are widely seen as an attractive substitute for plastic packaging, as they can be used with existing injection moulding equipment, the sophistication of materials and applications still remains a technological barrier.[172]

A long-term concern is 'that the continuous introduction of new engineered bio-based materials that are incompatible with existing industrial feedstocks could lead to the **contamination of product waste streams**, thereby making recycling more difficult and consequently constraining the current push towards a more circular economy.[173]

Cultural. Cultural barriers in applying bio-based construction materials relate to two common misperceptions: lower fire resistance and lower durability. In fact, thick layers of timber burn only on the outside. Just as a forest fire seldom takes down large trees, timber buildings burn at a slow and predictable rate,[174] while reinforced concrete collapses at high temperatures.[175] The durability of wood depends on whether the building structure keeps moisture out. That does require sometimes that concrete is used for the foundation.

3F. ENABLING CONDITIONS

Public awareness campaigns[176 177 178] help inform people of the advantages of regenerative construction materials and bio-based alternatives to conventional polymers used in consumer products. Coalitions of timber and construction companies, as well as architects and engineers, also support revisions of the building codes where needed.[179] Simultaneously, alliances,[180] conferences and roundtables are held on the topic of biopolymers, bioplastics and the bioeconomy in general to discuss and showcase examples, aiming to push the boundaries of what is perceived to be possible. Similar campaigns in low-income countries could help improve public perception of more traditional building materials.

Financial support is being offered to expand research and development on material innovations to reduce the consumption of fossil fuels.[181]

While the push from the private sector, establishing communities of practice and raising awareness are indispensable, policy remains a significant driver; 19 dedicated national and macro-regional bioeconomy policy strategies have already been developed over the past decade.[182]

Another enabler is the complementary availability of regenerative materials. Bamboo is often found in rapidly developing areas of the world where often timber resources are limited.[183]

CASE STUDY EXAMPLE: **BIOFIBRE FOR APPAREL AND AUTOMOTIVE INDUSTRIES LEATHER ALTERNATIVE MADE FROM PINEAPPLE WASTE, PHILIPPINES**

Piñatex™ is a leather alternative developed and commercialised by Ananas Anam. Piñatex™ aims to meet the growing demand for leather, but without the negative social and environmental impacts. Instead of animal hides, it uses waste pineapple leaves from pineapple farms. Biogas and organic fertiliser are by-products of the Piñatex's™ production process. The product is applied in the apparel, footwear, furnishing, car and aeronautic industries.

Local cooperatives in the Philippines produce fibres from the leaves through decortication: the extraction of biomass fibres. Since the cooperatives produce a higher-value-added product, the initiative grants farmers the chance to generate higher and more sustainable earnings. As women are involved in the decortication of biomass, the project also improves women's participation.

The fibres are then industrially processed into a non-woven mesh textile at a local factory to produce the basis of Piñatex, before being shipped to a finishing factory near Barcelona, Spain. The product allows for efficiency gains—the irregular shape of leather hides can result in up to 25% waste, yet these losses for Piñatex are just 5%. In addition, Piñatex does not use chemicals from the Cradle-to-Cradle list of banned substances, and the process is closed loop. Residual leaf biomass is used as natural fertiliser or biofuel. The non-woven Piñatexmesh is biodegradable.[184]

CASE STUDY EXAMPLE: **IBUKU'S GREEN VILLAGE COMMUNITY[181] SUSTAINABLE BUILDINGS USING TRADITIONAL CONSTRUCTION TECHNIQUES, INDONESIA**

Sustainable design can turn the construction industry and built environment into a net carbon sink rather than a source of GHG emissions. Locally harvested bamboo is used to build private homes at Ibuku's green village in Indonesia, for example.

The bamboo is treated with a natural and reusable boron solution to ensure the long-term quality of the material. The bamboo is then applied to different functions: from structural to furniture functions. The dwellings are based around radially located clusters of thick bamboo columns, while smaller beams are used to make chairs.

The environmental impact of the building is reduced through the application of regenerative construction materials, as the long-term application of wood acts as a net carbon sink.[186] The shift to low-carbon construction is associated with an average reduction potential of 0.1 tonnes CO_2e per capita, per year.[187]

For comparison, when applying cross laminated timber each cubic metre of wood sequesters an average of 0.8 to 0.9 tonnes CO_2.[188] Further benefits of applying bamboo in the case of Ibuku's green village is that local craftsmen and construction workers can work with bamboo.

Barriers remain as well since the use of non-bio-based resins, glues and artificial preservatives, in particular in engineered bamboo materials and composites, can make products unfit for recycling or upcycling.

INTERVENTION 4. REDUCING FOOD LOSSES FROM HARVEST TO PROCESSING

Enhance harvest methods and timing and improve the capacity to safely store, transport and process food products.

THIS INTERVENTION IN CONTEXT

This intervention aims to avoid food *losses*, which refer to food lost in the early phases of the food value chain, before it reaches the retailer or consumer. For a discussion on avoiding food *waste*—or unused food at the retail and consumption levels—see **Intervention five**. Where waste is unavoidable, it is used as a resource through the solutions proposed in **Intervention six**. Where losses at the farm level are unavoidable, they are used as a resource through the agricultural practices in **Intervention two**.

Sectoral scope	Waste management; Agriculture; Food processing; Land use
Synergy with GEF areas of operation	Biodiversity; Climate change; Food systems, land use and restoration; International waters
IPCC categories targeted	3B Land; 3C Aggregate sources and non-CO_2 emissions sources on land; 2B Chemical industry; 2H Other industries

4A. STRATEGY DESCRIPTION

Food loss and waste are estimated to be responsible for 8% of global emissions.[189] In Africa and Central Asia, 36% of food is lost and wasted. For Asia, this value is between 26 and 31%, and for Latin America 34%. In all these regions, more than half of the losses occur in the production, handling, storage and processing stages in the food value chain. For example, in Sub-Saharan Africa, 13% of the harvest is lost at the farm stage, during or just after harvest. Another 36% is lost during handling and storage, 3% during processing, 6% during distribution and retail and 5% at the consumer stage. This makes a total value chain loss of 36%.[190]

Food losses are caused mainly by poor storage facilities and lack of infrastructure, lack of processing facilities, demand uncertainties and inadequate market linkages.[191 192] As a result, solutions to reduce losses involve **preserving and extending what's already made**, through storage and handling solutions that limit crop exposure to moisture, heat and pest infestation—for example, hermetic bags, metal silos or gum arabic coating that prevents the ripening of fruits and vegetables.[193] Processing solutions can also be implemented, specifically those which limit the handling and transportation of raw crops and that increase their shelf life, like mobile processing units, solar dryers, graters and pressers.[194] Solutions also involve **collaborating to create joint value**, through improvement of procurement channels to allow for the efficient transfer of crops from producers and agro-processors to consumers—for example, through the use of technology platforms that connect farmers and potential buyers, or through contract farming, direct sourcing or collection centres.[195]

4B. GREENHOUSE GAS MITIGATION POTENTIAL

9 to 51 billion tonnes CO_2e between 2020 and 2050 for industrialised Asia, North Africa, West and Central Africa, Latin America, South and Southeast Asia and Sub-Saharan Africa. This value is based on the global figures from the IPCC, which have been downsized to the specific geographies covered by the GEF.[196] By reducing food loss, emissions from the production of food that does not reach the consumer are avoided. In addition, emissions from the disposal of organic waste in landfills, dumpsites or surface waters are reduced.

This range is consistent, although at the lower end of the 87 to 95 billion tonnes CO_2e for the 2020–2050 global estimate of the mitigation potential from food waste and losses taken together by Project Drawdown. According to Project Drawdown, reducing food waste and losses is the mitigation option with the largest global potential.[197]

The estimated emissions mitigation potential associated with reducing food losses and waste, from the 2019 IPCC special report on Climate Change and Land,[198] can be split across different stages of the value chain.[199] This global figure was further scaled-down to GEF countries of operation by excluding nations in Europe, North America and Oceania.

First, total food loss and waste was calculated per region, based on per capita figures from 2007.[200 201] As per capita figures do not distinguish between losses and waste, data from the WRI was used to split these figures proportionally.[202]

4C. BUSINESS CASE POTENTIAL

Medium/high. Reducing food losses can be economically feasible for all actors along the supply chain.[203 204 201] The annual market value of the food that is lost and wasted along the full value chain is estimated at US$940 billion,[206] approximately half of which relates to food losses and half to food waste (Intervention five). Project Drawdown estimates the global economic, environmental and social cost of food loss and waste at US$2.6 trillion.[207]

Post-harvest loss solutions vary in their cost-effectiveness. Solutions with the highest return on investment (where returns also include social and environmental returns such as advancing health or securing livelihoods) include 1) storage and transport solutions that are relatively inexpensive to manufacture and/or procure, but with significant post-harvest loss reduction gains, and 2) the expansion of procurement channels.[208]

4D. CO-BENEFITS

Reducing food losses from harvest to processing improves the overall efficiency of the food value chain. This reduces GHG emissions and improves **climate resilience**. The latter is important since avoiding losses allows food systems to increase the volumes that reach the consumer, without increasing the need for land or other agricultural resources like labour, mechanical operations and agrochemicals.

Reducing food losses in turn reduces the need to allocate land to the production of food products that never reach the consumer.[209] As such, avoiding food loss helps protect terrestrial ecosystems, preserve **biodiversity** and **prevent further degradation of land**. Where agricultural systems rely on agrochemicals it could also reduce **chemicals and waste**.

Estimates indicate that reducing the current rate of food loss and waste by 50% by 2050, would prevent the conversion of an area of natural ecosystems roughly the size of Argentina into agricultural land between 2010 and 2050.[210] Since agriculture irrigation accounts for 70% of global water use,[211] halving food loss and waste by 2050 would also reduce freshwater use by about 13%,[212] and **enhance water security**.

Furthermore, **food security** could be improved as a lack of access to food is often related to availability. Preventing food losses at the local level in smallholder production would have the biggest impact, alleviating food shortages, increasing farmers' incomes and improving access.[213] Reducing food loss and waste by 50% by 2050 would close the gap between food needed in 2050 and food available in 2010 by more than 20%.[214]

The socio-economic benefits for stakeholders along the value chain are derived from the fact that reducing losses increases income, since a larger share of the harvest or processed food volumes reaches the market.[215 216] However, the impact on job creation is expected to be modest.[217]

4E. BARRIERS

Economic and financial. Farmers often lack funding to invest in reducing food losses and lengthening the shelf-life of their products. For the larger food processing companies, this is less of an issue. Additionally, data or case evidence that demonstrates the potential or impact of investments in reducing food losses is often lacking.[218] Low food prices are another barrier to investments.[219] Costs and savings vary considerably across geographies.[220] Once stakeholders are aware of the opportunity and have been provided access to finance and technical means, they often take voluntary action.

Legal, regulatory and institutional. Food losses between harvest and processing is seldom a political priority, even though the co-benefits related to food security and the environment are often featured high on the political agenda.

Technological. Food losses require an investment in storage capacity, market information to better match supply and demand, and sometimes additional processing steps to preserve the food longer. These are typically readily available technologies but can be difficult to access in some regions, for example where agriculture is dominated by smallholders.

Cultural. As people's disposable income rises, the focus of the losses tends to shift from farmers and processing to retail and consumers, thus increasing disposable income is a way to reduce food losses. In fact, since many GEF target countries have a growing middle class, investments are required to reduce losses and avoid the growth of food waste.

4F. ENABLING CONDITIONS

Initiatives to reduce food losses that go hand-in-hand with investments to improve production, like regenerative agriculture and nutrient management, is an enabling factor. Such a value chain approach, which involves all steps in the food value chain, can also secure higher revenues when a larger share of the harvest reaches the market, and thereby is more likely to be successful.

Since there are large differences across geographies in the costs and savings of interventions to reduce food losses, demonstration projects should showcase the relevance and effectiveness of particular approaches in a specific region.

As food losses are especially high in regions that periodically suffer from food deficits, reducing food losses should be higher on the political agenda. Capacity building and awareness raising can help connect food losses with food security, and secure more political attention and stakeholder support.

There is also an ethical angle to reducing food waste. Many people consider it to be simply 'the right thing to do' in a world where many people still suffer from malnourishment.[221] This helps build political momentum, awareness and behavioral change and eases access to funding for initiatives that target food waste and losses.

CASE STUDY EXAMPLE: COLDHUBS SOLAR-POWERED, COOLING-AS-A-SERVICE SOLUTION

ColdHubs is a post-harvest, solar-powered, cooling-as-service solution in Nigeria. By offering a solution to store and preserve perishable foods that adequately meet the financing needs of smallholder farmers, ColdHubs is an effective solution to the issue of post-harvest losses in fruits, vegetables and other perishable foods in Sub-Saharan Africa.

ColdHubs are installed in major food production and consumption centres (markets and farms). There, farmers place their produce in clean plastic crates, which are stacked inside the cold room. Farmers and retailers pay ₦100 (US$0.50) to store one 20 kilogram returnable plastic crate per day.[222] This extends the freshness of fruits, vegetables and other perishable food from two days to about 21 days.[223]

In 2019, the 24 operational ColdHubs saved 20,400 tonnes of food from spoilage, increased the household income of their customers (3,517 smallholders, retailers and wholesalers) by 50%, created 48 new jobs for women, and mitigated 462 tonnes of CO_2 emissions, with an annual energy consumption reduction of 547 kilowatt-hours.[224 225]

ColdHubs offers farmers a flexible pay-as-you-store subscription model at rates that they can afford, helping to tackle the barrier of access to financing for cold chain solutions.

INTERVENTION 5. AVOIDING FOOD WASTE AT THE RETAILER AND CONSUMER STAGES

Reduce food waste through improved inventory management, the development of secondary markets for imperfect food products or products near their expiry date and improved value chain management.

THIS INTERVENTION IN CONTEXT

This intervention aims to prevent food waste and relates to the latter phases of the food value chain:retail and consumption. For a discussion on avoiding food *losses* in the earlier phases of the value chain, see **Intervention four**. Where waste is unavoidable, it is used as a resource through the solutions proposed in **Intervention six**. Where losses at the farm level are unavoidable, they are used as a resource through the agricultural practices in **Intervention two**.

Sectoral scope	Waste management; Agriculture; Food processing Land use
Synergy with GEF areas of operation	Biodiversity; Climate change; Food systems, land use and restoration; International waters
IPCC categories targeted	3A Livestock; Land; 3C Aggregate sources and non-CO2 emissions sources on land; 2H2 Food and beverages industry; 4 Waste

5A. STRATEGY DESCRIPTION

Food production is responsible for 26% of global emissions,[226] but a third of all food does not reach the consumer. In Latin America, North Africa and the Middle East, food waste at the retail and consumer stages is responsible for 30% of all food losses and waste. For Sub-Saharan Africa, this figure is only 5 to 13%, while for high-income countries, it reaches 50 to 60%.[227]

Preventing food waste requires **collaboration to create joint value**, in particular across food value chains. For the production of food, a range of scarce resources are used, including seeds, water, energy, land, chemicals and labour; thus, ensuring these products actually feed people is a more effective use of resources.

Preventing food waste involves most key elements of the circular economy. It requires **rethinking the business model** to sustain and **preserve what's already made**, through the development of markets for surplus food, products nearing their expiry dates or imperfect products, and by integrating these into food business menu planning, product lines and marketing. **Collaborating to create joint value** also has a key role through collaboration within the supply chain on standardised date labelling, and consumer education campaigns, while discouraging retail marketing campaigns aimed at purchasing excessive volumes of food from retailers, such as discounts on large quantities. **Designing for the future** and **for minimal waste** come into play through improved packaging and coatings, perhaps allowing for resealable and reusable packaging. Finally, **digital technology must be incorporated** to improve inventory management and prevent waste due to mistakes in logistics, planning, forecasting and cold chain management at the retail level.[228]

5B. GREENHOUSE GAS MITIGATION POTENTIAL

5.7 to 32 billion tonnes CO_2e between 2020 and 2030 for industrialised Asia, North Africa, West and Central Africa, Latin America, South and Southeast Asia and Sub-Saharan Africa.[229,230]

As in the previous intervention, this range is also consistent, although at the lower end of the 87 to 95 billion tonnes CO_2e for the 2020–2050 global mitigation potential estimate for food waste and losses from Project Drawdown.[231]

The estimated emissions mitigation potential associated with reducing food losses and waste, from the 2019 IPCC special report on Climate Change and Land,[232] can be split across different stages of the value chain.[233] This global figure was further scaled-down to GEF countries of operation by excluding nations in Europe, North America and Oceania.

First, total food loss and waste was calculated per region, based on per capita figures from 2007.[234,235] As per capita figures do not distinguish between losses and waste, data from the WRI was used to split these figures proportionally.[236]

5C. BUSINESS CASE POTENTIAL

High. Reducing food waste is often a positive financial opportunity for all actors along the supply chain.[237,238] Investments in food waste reduction are often incentivised by legal obligations, also when they are not commercially attractive. This may hamper long-term adoption and commitment.[239]

5D. CO-BENEFITS

The co-benefits of reducing food waste largely overlap with those from reducing food losses. Although the strategies intervene in different parts of the value chain, their co-benefits mostly relate to improving overall value chain efficiency and thereby reducing the environmental impact of agricultural production.

In brief, cutting food waste at retail and consumption stages reduces GHG emissions and improves **climate resilience** and food security. It also reduces the need to allocate land to the production of food products that never reach the consumer,[240] and thereby supports **biodiversity**, preventing further **degradation of land** and reducing the application of agrochemicals. In addition, as the irrigation of agricultural land accounts for 70% of global water use,[241] reducing food waste can **enhance water security in freshwater systems**.[242]

Initiatives that connect leftover food with demand can also create new **job opportunities** and improve **food security** by providing low-income consumers with access to high-quality food products at a reduced price, as illustrated in the Tekeya case study.

5E. BARRIERS

Economic and financial. It is difficult to get funding for activities that target reductions in food waste at retail and consumer levels because there is often not enough data to quantify impact.[243] In some cases, the investments in reducing food waste don't pay off, which is also related to food products' low prices. Finally, in some cases, retailers are reluctant to donate residual food for fear of food poisoning when expiry date margins are small.[244]

Legal, regulatory and institutional. In many countries, food waste from retail and consumers is a new issue, emerging from increasing incomes. It is often not a political priority, despite its co-benefits with high political priorities—the income levels of large numbers of smallholder farmers and food security.

Technological. Food waste is not a very technical issue. Most of the technology required is available but underutilised. Educating retailers and consumers on food waste is important to increase awareness.

Cultural. As people's disposable income rises, food waste increases. In some cultures, offering large volumes of food to visitors is associated with hospitality or status. There are also perceptions that reducing food waste reduces farmers' income. Producing excess volumes of food is sometimes also considered an insurance, whereby losses are factored in as a mere 'cost of doing business'.

5F. ENABLING CONDITIONS

Enablers are political will and the use of public-private partnerships. Governments will need to seek collaborations with the private sector—including national agriculture and environment agencies, research institutions and food businesses, from producers and manufacturers to retailers, restaurants, and hospitality companies—to tackle food loss and waste. Such partnerships are important to support collaboration along the entire food supply chain, identify hotspots for action and implement supportive public policies to address them.[245]

Next to this, it is important that governments involve the private sector in policymaking: involving the full range of government bodies that oversee agriculture, environment, public health and nutrition.

Startups can also play an important facilitating role in matching residual food with demand. Initiatives that support startups and provide access to office spaces, financing and perhaps workshops can help address the socio-economic and environmental issues that some startups target.

CASE STUDY EXAMPLE: **TEKEYA APP REDISTRIBUTING SURPLUS FO OD TO CONSUMERS AND CHARITIES IN EGYPT**

In the Middle East and North Africa, food waste at the consumption level amounts to roughly 85 kilograms per person per year.[246] Tekeya is a mobile app that connects hotels, restaurants and retailers that have leftover food with consumers who want to order fresh food at a reduced price. The app also connects businesses with charity organisations so that any unsold surplus food at the end of the day is donated to those in need.[247]

The Tekeya app targets unserved ready meals or baked goods in restaurants, previously refrigerated items or uneaten buffet servings. Some users use the app to donate food to those in need while others use it to sell food products that are close to their expiry date at a reduced price.[248] The app also enables food businesses to estimate their waste and presents suggestions on how to reduce it.[249]

The application does not rely on donations and has its own business model and revenue streams.[250] It also offers an additional revenue stream for food companies, which can sell food that would have otherwise been thrown away. The app also creates valuable brand exposure and public awareness of the issue of food waste.[251] After its initial success, it is being expanded to several provinces in Egypt. There are plans to expand further into the rest of the Middle East and the North African region.[252,253] Similar business models exist in Europe and have succeeded at scale, such as Too Good to Go.[254]

The app was launched in 2019[255] and is already working with 405 businesses in Egypt, has saved 3,800 meals and prevented 9.5 tonnes of CO_2 emissions. The founder of Tekeya indicated that there are cultural barriers to using food waste;[256,357,358] while initially restaurants feared reputation damage from using the app, this perception has changed and they now see the positive exposure it creates.[259]

INTERVENTION 6. CLOSING THE LOOP ON URBAN ORGANIC RESIDUES

Recover and separate organic residues from urban solid waste and wastewater for composting, biogas production, water and nutrient recovery to support urban and peri-urban farming.

THIS INTERVENTION IN CONTEXT

The solutions in this intervention address food *waste* in the city. They are end-of-life solutions that should be considered last, after the solutions outlined in **Interventions four and five**. The latter help to reduce food losses earlier in the value chain and to prevent food from becoming waste altogether. Where food losses at the farm level are unavoidable, they are used as a resource through the agricultural practices in **Intervention two**.

Sectoral scope	Waste management
Synergy with GEF areas of operation	Food systems, land use and restoration; Climate change; Sustainable cities; International waters; Chemicals and waste
IPCC categories targeted	4A Solid waste disposal 4B Biological treatment of solid waste 4C Incineration and open burning of waste 4D Wastewater treatment and discharge

6A. STRATEGY DESCRIPTION

The anaerobic decomposition of organic material in landfills and dumpsites is responsible for 12% of global methane emissions,[260] and GEF countries of operation are the origin of more than half of these emissions.[261 262]

Under business-as-usual, these figures are set to increase. Waste disposal tends to rise concurrently with income and population levels. The daily per capita waste generation figures for low- and middle-income countries are expected to increase by approximately 40% or more in 2050.[263] This is especially problematic as low-income countries only collect 48% of waste in cities and as little as 26% outside of urban areas.[264]

This intervention aims to prevent the disposal of valuable organic materials, water and nutrients. By **using organic waste and wastewater as a resource** through composting, anaerobic digestion, wastewater reuse and wastewater nutrient recovery, cities can divert such waste from landfills and dumpsites.

One of the strategies of nutrient recycling is phosphorus recovery. The recovery of this essential plant nutrient from organic residues can mitigate the negative consequences of mineral phosphorus application for ecosystems, including loss of biodiversity due to eutrophication. In the long-term it may prevent increased food prices due to 'phosphorus peak'.[265]

These processes also facilitate the production organic fertilisers, which, when compliant with regulations, can be safely returned to urban and peri-urban farms to regenerate soils,[266] allowing for the **prioritisation of regenerative resources**. This lowers the demand for synthetic fertilisers and fossil fuels, thereby reducing the emissions associated with their production and application. Under the right conditions, the reuse of wastewater—for example, to irrigate crops—can also serve a similar purpose, by reducing the amount of energy that would have otherwise been required to treat water and bring it to a potable standard.[267]

A key prerequisite for these processes is the effective collection of separated, uncontaminated organic streams and wastewater.[268] The infra-structure and logistics to support this can vary in scale and level of decentralisation. They cover household level, backyard or community composting, to large-scale industrial anaerobic digesters; from augmenting existing, centralised waste-treatment plants with additional pipelines for delivering recycled water,[269] to decentralised networks of urban metabolic hubs that harness clean water, energy, nutrients and minerals from wastewater and organic waste such as the Biopolus.[270]

Finally, working on both creating a *supply* of organic fertilisers and on stimulating the *demand* for these fertilisers through urban and peri-urban farming (UPAF) allows the creation of local, closed-loop urban systems that bypass the need for long-distance transportation and its associated emissions. These small-scale, local loops also have other advantages, for example, making these processes more cost-effective as they become more economically feasible if the point of (re)use is closer to the point of production.[271 272]

6B. GREENHOUSE GAS MITIGATION POTENTIAL

1.5 to 2.2 billion tonnes CO_2e in the 2020 to 2050 timeframe. This estimate is based on the global mitigation potential of composting urban organic waste that is largely being managed today via landfills and, in some regions, open dumping: 2.14 to 3.13 billion tonnes CO_2e[273] between 2020 and 2050. This global figure was corrected for the estimated 70% of global methane emissions from waste management stemming from East Asia and Pacific, Latin America and the Caribbean, the Middle East, North Africa and Sub-Saharan Africa, geographies that largely overlap with the GEF countries of operation.[274] Since the countries with an economy in transition are not yet included in the 70%, the actual figure is likely to be even slightly higher.

Urban agriculture can mitigate emissions mainly by reducing urban heat island effects[275] and the substitution of food from 'normal' food supply systems,[276] which rely on the assumption that reduced food miles also reduce the system's overall carbon footprint. However, this is not always the case, as some urban food systems are less efficient than conventional ones and might require more energy to sustain themselves.[277 278] Another understudied factor is the (potentially) positive relationship between urban agriculture and composting. More data is needed to evaluate the net emissions savings of urban agriculture in developing countries and cities. Developing indicators and monitoring frameworks to better understand the actual contributions of urban agriculture to climate change adaptation, mitigation and disaster risk reduction are also needed.[279]

6C. BUSINESS CASE POTENTIAL

Low. The investment is more or less on par with the monetary savings over a 30 years timeline. Composting requires an investment of US$64 billion worldwide, while saving US$61 billion between 2020 and 2050.[280]

6D. CO-BENEFITS

Next to reducing GHG emissions from the decomposition of organic waste in landfills, the collection and processing of urban organic waste can also improve **climate resilience**. This is because soil application of compost or digester sludge helps improve soil fertility, soil life and water retention.

Urban and peri-urban farming can help to build **resilient urban food systems** at the city or regional level, with positive impacts on **food security,**[281] **health, urban environmental management, social inclusion, community building** and **local economic development**.[282 283] Agricultural production in cities, for example, often provides the poorest of the urban poor with greater access to safe and nutritional food, which in turn, helps improve their health.[284] It also favours social inclusion and the reduction of gender inequalities, as 65% of urban farmers are women.[285]

Diverting waste from landfills increases the lifespan of waste disposal facilities, which saves valuable **land resources**. Nutrient recovery from wastewater also offers a sustainable alternative to **scarce resources** with extractable mineral phosphorus resources predicted to become insufficient or even exhausted over the next decades.[286]

The accumulation of methane in landfills is also a **safety and health** risk for people working and sometimes living at or near the landfill, as landfills are more likely to catch fire[287] due to the spontaneous combustion of decomposing waste involving methane. Removing organic matter from the waste stream also reduces odor nuisance and enhances recycling and waste management operations.[288]

Reduced landfilling of organic material will also reduce leachate from landfills, which **enhances water security and groundwater systems**. The reuse of wastewater for agriculture provides a similar ecosystem service, as it reduces the need for freshwater abstractions and allows fisheries and other aquatic ecosystems to thrive by minimising water pollution and recharging depleted aquifers.[289]

If a business model is found, organic waste management can also **create jobs**. This ranges from the separate collection of organic waste, to the supply of decentralised or centralised composting or anaerobic digestion facilities, their operation and the commercial use of biogas as an energy source. When job creation is coupled with a business model that allows for improved working conditions, people's **livelihoods** can improve. Urban agriculture favours **social improvement**, as the poor spend up to 85% of their income on food, and most urban farmers belong to the poorest populations.[290]

6E. BARRIERS

Economic and financial. Organic waste management initiatives face difficulties in securing finance. The revenue generated from the sale of compost will rarely cover processing, transportation and application costs, and often an adequate marketing plan is lacking for the compost. This is not helped by the poor accounting for negative externalities, such as methane emissions from landfilling organic waste; nor costs related to diverting organic waste from processing and use as a fertiliser and soil enhancer,[291] the abstraction of freshwater,[292] soil degradation and erosion, water contamination, climate change and waste disposal costs.

The rapid growth of cities in developing countries also leads to land value increases that limit land access for urban farmers, who often occupy marginal lands with low fertility. Other than limiting their productivity, these lands also strongly reduce the choice of species they can cultivate.[293]

Technological. The lack of reliable data hampers proper waste management and planning. City administrations often don't know how much waste they generate, nor its composition. Furthermore, informal waste collection by waste pickers is seldom a very effective way to collect and sort waste.[294]

The current lack of infrastructure for collection and treatment is one of the main challenges facing improved wastewater management and the expansion of urban farming in developing countries.[295 296] As cities expand quickly, they struggle to keep up with the demand for municipal services. As a result, the level of air, soil and water pollution in cities makes growing healthy food more difficult, as the risk of contamination is higher.

Other technical barriers relate to the strong emphasis placed on mechanical rather than biological treatment of waste, the use of inadequate feedstock which yields poor quality finished compost, for example, heavy metal contamination.[297]

Legal, regulatory and institutional. Since waste collection is often part of the informal sectors in low- and middle-income countries, proper data on waste volumes is often lacking and workers operate outside the health, safety and income legislation which should protect their rights. Formalising workers at landfills is often required to make landfill management safe.

6F.ENABLING CONDITIONS

Organic waste is a valuable resource which can be used to improve soil quality. This, inturn, can increase agricultural and biogas production. This could reduce the import of fossil-based fuels and fertilisers. On the flip side, composting can be initiated with very little capital and operating costs.[298]

The political will is often there, but might compete with the more pressing need to provide adequate waste collection. Separate organic waste collection,[299] and overall solid waste management, both tend to be high on the political agenda[300] as many urban and rural residents are exposed to the adverse impact of inadequate waste management systems.[301]

Proposed waste management solutions need to consider many factors to be successful:[302] how to engage with citizens and communicate about the initiative, for example, but also various logistics aspects. These range from how ambient temperatures will impact collection frequency to whether collection bags are provided to people for free or at a fee.

Careful consideration of the interests of different stakeholder groups is also important. The use of cooperatives, for example, can provide legal protection to workers involved in waste collection and improve data collection. Private sector participation can create a market for organic soil enhancer from compost or digester sludge. Where there is no waste collection in place, community initiatives can be an alternative form of organisation. In this case, decentralised composting facilities can provide a soil enhancer for gardens, parks or for sale.

CASE STUDY EXAMPLE: COMPOSTING IN SÃO PAULO

Decentralised composting yards collecting and composting organic waste from street markets and households

São Paulo, Brazil, has 883 street markets which generate 34,000 tonnes of organic waste per year. The municipality generates an additional 39,000 tonnes from tree and plant pruning. A system of decentralised composting locations allows São Paulo to divert organic waste from landfills and produce compost. The composting facilities, or 'yards', handle up to 50 tonnes of waste a day and, in 2018, were estimated to prevent about 1,920 tonnes of CO_2e emissions annually.[303] As a result, compost from street markets is used in the maintenance of public spaces in the city. However, these maintenance activities were estimated not to be enough at the moment to absorb 100% of the compost production foreseen in the city's Integrated Solid Waste Management Plan,[304] so compost is also sometimes given away for free to visitors. The project also includes an urban garden programme in which citizens are encouraged to grow their own food.[305]

The implementation of the project was one of piloting and careful upscaling. When experience with the first composting yard was positive, five more were opened. The capacity of these six yards is around 15,000 tonnes of organic waste per year.[306]

The composting yards have an educational purpose since they enable citizens to familiarise themselves with the process of composting and the importance of organic matter for food production. Composting facilities are regularly visited by schools, local authorities and people interested in gardening and compost use. One of the facilities also has a plant nursery.

The initiative also has health benefits, as waste collection at markets has improved, supported by special bags made available by the composition yards. The project creates employment since each composting yard employs four to five staff. In addition, the centralised location of the yards close to the markets reduces waste logistics in the city.[307]

Important lessons have been learned from the project. The quality of the compost is important to effectively use it as a soil enhancer for parks and food production. To produce compost of high quality, the feedstock needs to be clean. This requires educating the market staff to make sure there is proper source separation in place. The decision to realise small-scale composting facilities first allows for the local population to get closer to the production of compost. Other lessons learned relate to the low-tech nature of the solution. It did not require big investments and can be quickly deployed and scaled.[308]

INTERVENTION 7.
REDESIGN, REUSE, REPAIR, AND REMANUFACTURE OF PRODUCTS AND RECYCLING OF GLASS, PAPER, METALS AND PLASTICS

Enhance the collection, sorting and processing of materials and recyclables, diverting waste from landfills and incineration to increase the availability of secondary resources.

Sectoral scope	Solid waste management; Industry; Consumer goods and packaging
Synergy with GEF areas of operation	Climate change; Sustainable cities; Chemicals and waste;' International waters
IPCC categories targeted	2A3 Glass production 2C3 Aluminium production 2H1 Pulp and paper industry 4A Solid waste disposal 4B Biological treatment of solid waste 4C Incineration and open burning of waste

REDESIGN, REUSE, REPAIR AND REMANUFACTURE OF PRODUCTS AND RECYCLING OF GLASS, PAPER, METALS AND PLASTICS

Recycling and designing for circularity reduces primary resource extraction and related CO_2 emissions throughout the value chain.

Note that the flows in this graph are indicative only and aim to illustrate extreme opposite scenarios.

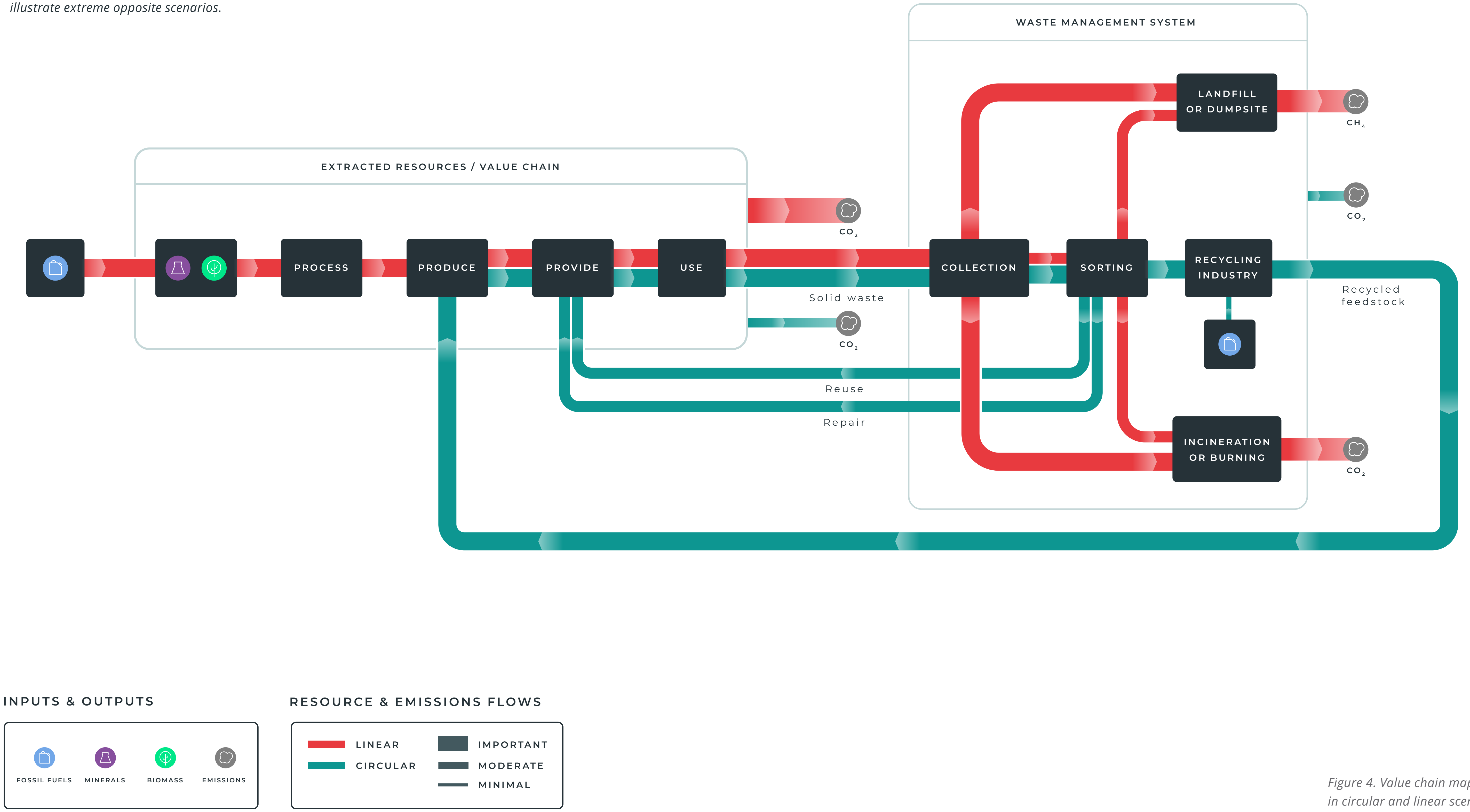


Figure 4. Value chain mapping in circular and linear scenarios.

7A. STRATEGY DESCRIPTION

The global solid waste volume is 2.01 billion tonnes annually.[309] In low-income countries, materials that could be recycled like paper, cardboard, plastic, metal and glass account for 20% of the waste stream.[310] However, the fastest-growing regions are Sub-Saharan Africa, South Asia, and the Middle East and North Africa, where, by 2050, total waste generation (not just that of recyclables) is expected to more than triple, double and double, respectively.[311]

Recycling taps into using **waste as a resource**. It reduces the volume of waste, while on the other hand, provides secondary raw materials to substitute primary extraction. 62% of global GHG emissions stem from the extraction, processing and production of materials and fuels.[312] Next to this, 70% of global GHG stems from material management.[313] Next to this, the carbon footprint of nearly all recycled materials is lower than that of similar products and materials from primary resources.[314] However, the use of secondary resources is only a means to reduce GHG emissions if options for reuse, remanufacturing and repair have been depleted, and the separation of materials is accurate and the recycling well-organised.[315] The reduction in the extraction of virgin raw materials can help bring down global GHG emissions, while reducing the volumes of waste going to landfill, dumpsites or being combusted.

The extent to which product and material lifecycles can be extended depends on whether they are **designed for the future** and existing enablers for reuse, remanufacturing and repair. If products are designed for disassembly, for example, or if they do not contain hazardous materials, recycling is easier and safer. Some GEF countries of operation produce substantial amounts of materials for domestic use and exports. Importing countries can adopt standards and legislation requiring that imported goods and materials can be recycled.

This intervention partly overlaps with the previous, as both interventions require the separate collection and sorting of waste. The opportunities also show synergies where the collection of waste and recyclables involves an informal workforce and thereby represents an opportunity for the empowerment, inclusion and improvement of working conditions of the labour force.

7B. GREENHOUSE GAS MITIGATION POTENTIAL

5.0 to 6.0 billion tonnes CO_2e between 2020 and 2050 globally. This includes the global figures for recycling of household and industrial waste other than paper and organic waste (5.50 billion tonnes CO_2e globally) and recycled paper with a global mitigation potential of 1.10 to 1.95 billion tonnes CO_2e between 2020 and 2050.[316] These figures have been adjusted for the share of industrial GHG emissions that stem from non-OECD countries. This share is 75%.[317]

7C. BUSINESS CASE POTENTIAL

Medium/high. The recovery and processing of industrial and household waste, excluding paper, requires a global investment of around US$11 billion, while saving operational costs of US$238 billion between 2020 and 2050.[318] For paper recycling these figures are unavailable.

7D.CO-BENEFITS

The recycling of glass, plastics, metals and paper reduces GHG emissions from primary resource use. In addition, the improved collection and sorting of waste, as well as improved disposal in sanitary landfill can help reduce environmental impacts from unregulated disposal and open burning. Dumpsites and the burning of waste can cause **soil degradation, freshwater and air pollution**[319 320 321] with toxic chemicals and persistent organic pollutants (POPs). These materials cause health issues when they accumulate in fauna and flora and along the food chain.[322]

Furthermore, recycling helps reduce waste flows going to landfills, thereby prolonging their lifetime.[323] When organising waste collection and sorting, it can help improve **labour conditions**, notably health and safety, and create **new jobs**. Since the unregulated disposal of plastics in waterways causes these waterways to block, recycling can also improve climate resilience by keeping drainage canals and rivers open.[324]

7E.BARRIERS

Economic and financial. Municipalities often lack the means to invest in and operate a solid waste management system which is formalised, offers safe and healthy working conditions and a decent salary.

Legal, regulatory and institutional. An informal workforce manages most waste flows in low- and middle-income countries. Alongside this, a lack of capacity to enforce waste legislation makes it difficult to put a price on waste or a penalty on pollution, even if such measures would create an incentive for recycling.

The informal status of workers in waste management is a barrier to the social acceptance of their activities as a legitimate economic activity. There remains a debate on the best way to resolve this: by formalisation, integration or professionalisation. The OECD notes that 'the best-functioning systems are those which embrace an open strategy that includes both informal collectors and the existing value chain enterprises in the system'.[325] In practice, it may require a combination of formalisation, integration and professionalisation, depending on the specific context.[326 327]

On the other end of the value chain, legislation might also hamper recycling efforts. This occurs when the classification of waste inhibits its processing, for example, legislation on the processing of hazardous waste which hinders its recycling.[328] However, simply abolishing this legislation may re-open the door for low-cost, but improper, disposal or treatment. Furthermore, some product standards do not allow or encourage the use of recycled content.[329] This is an issue mainly in food packaging, where food safety needs to be safeguarded.

Technological. Without having a proper waste collection system in place, cities lack information on waste volumes and composition, making it difficult to oversee the value that is lost due to the untapped recycling potential.

This information is important for developing a business case for collection, sorting and recycling.

Looking at the technical cycle, plastic recycling is hindered by the health risks posed by toxic chemical additives, including POPs.[330] Similar issues occur in textiles, where the lack of traceability of most textiles available for recycling carries the risk of re-introducing materials into the market that could pose a threat to product safety due to chemical contamination.[331] In the EU, for example, the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) safety regulations aim to regulate the use of harmful chemicals in products.[332]

Technology can also pose barriers to recycling. Waste incineration can create a lock-in effect whereby the available capacity needs to be properly used.[333] Plastics, for example, have a relatively high calorific value, sometimes exceeding that of dry wood or coal,[334] which makes them a valuable fuel for waste incinerators.

Cultural. Development projects often try to address urgent waste issues in low- and middle-income countries. Many projects, however, fail to understand the whole waste management process—which should be the project's starting point. Next to this, the implementation timeframe is often too short to allow instructions and stakeholders to develop along with the solution presented and thereby ensure adoption, ownership and project permanence.

7F.ENABLING CONDITIONS

Successful waste management and recycling initiatives are enabled with data collection, capacity building and funding. Data collection is important for understanding the volume and composition of waste flows, but also for overseeing and understanding the role of formal and informal stakeholders in the waste sector. Capacity is required to allow municipalities or waste management entities to develop business models that help develop long-term perspectives and attract financing. Important financial enablers of functioning waste management and recycling systems are schemes that provide a sustainable revenue source. An example is Extended Producer Responsibility, whereby the producer is responsible for the proper management of the waste its products or services generate. Such a scheme should be set up to encourage producers to design out waste altogether.

Middlemen can divert revenues from the sale of recyclable materials away from those that do the waste collection and sorting. Organising waste pickers in cooperatives can enhance their bargaining power and give them direct access to the demand for recyclable materials. Besides, a well-organised waste management system can also attract new private sector initiatives, as a more reliable flow of recyclable material becomes available. A cooperative also allows workers to register and obtain a safe workplace and perhaps more job satisfaction. They may even gain the status of civil servant.

Cooperative members consistently report a higher standard of living as well as improvements in self-esteem and self-reliance, compared to when they work independently. In addition, organised workers are more productive and are healthier when provided with guaranteed collection routes and safe working conditions outside of dumpsites.[335]

CASE STUDY EXAMPLE: **A PUBLIC-PRIVATE WASTE MANAGEMENT COOPERATIVE**

Cooperative SWaCH provides doorstep waste collection, repair and recycling services in Pune, India

In 1993, waste pickers and itinerant waste buyers in Pune and Pimpri Chinchwad formed a membership-based trade union. This formalised waste pickers, allowing them to access insurance, loans and educational support for their children. In 2005, the union collaborated with Pune Municipal Corporation to integrate waste pickers in the door-to-door waste collection system, which further solidified their status. It also led to the establishment of a workers' cooperative fully owned by its employees, called SWaCH. Its board comprises waste pickers and municipal and union representatives.

Since 2008, SWaCH provides a decentralised door-to-door collection of solid waste, whereby recyclable and organic materials are separated. The remaining non-recyclable fraction is dropped off at municipal 'feeder points,' from which municipal garbage trucks carry it to landfill. This system is more cost-effective for the municipality as it saves the costs of waste collection and reduces the volumes that go to landfill.

SWaCH collects over 850 tonnes of municipal solid waste per day, of which around 150 tonnes is recycled and 130 tonnes is composted. The organisation currently supports further waste separation since it installed e-waste collection points in private and government organisations, schools and colleges. Citizens can also drop off their e-waste at the SWaCH offices or opt to have it collected directly from home. Where possible, the e-waste is repaired and sold again while the remainder is dismantled and recycled.

In 2018 SWaCH reported that it collects 398,580 tonnes of waste annually, of which 71,744 tonnes are diverted from landfills. As such, the organisation contributes to a reduction of landfill gas emissions of 184,609 tonnes CO_2e, while reducing energy use by 1,793,036 million British thermal units.[336]

INTERVENTION 8.
MAKE THE RENEWABLE ENERGY TRANSITION CIRCULAR

Implement a life-cycle approach to renewable energy generation and storage capacity through design for disassembly, improved repairability, circular business models and the use of recycled metals.

Sectoral scope	Energy; Industry; Waste management
Synergy with GEF areas of operation	Climate Change; Biodiversity; Chemicals and waste; Sustainable Cities
IPCC categories targeted	1A1 Energy industries 1A2 Manufacturing industries and construction 1B3 Other emissions from energy production 2E3 Photovoltaics

8A.STRATEGY DESCRIPTION

With global economies looking to become climate neutral or fossil fuel-free it becomes clear that the metals used in clean energy production and storage technologies are scarce. Therefore, we need to **prioritise truly regenerative resources** and non-critical metals for the production of renewable energy infrastructure.

An important indicator of the renewable energy transition's progress in the power sector is the share of low-carbon technologies (renewables, nuclear and carbon capture and storage) being used. In 2019, 37%[337] of generation came from low-carbon technologies—an increase of just over 1% from 2018. In 2019, renewable electricity generation rose by 6% and reached almost 27% of global electricity generation, the highest level ever recorded.[338] Solar photovoltaics (PV) and wind each accounted for about one-third of total 2019 renewable electricity generation growth, with hydro representing 23% and bioenergy most of the rest. Combined with weak electricity demand growth, in 2019 renewables expansion outpaced the total rise in electricity generation for the first time during a period of global economic expansion. Generation from renewables expanded more quickly than generation from any other fuel, including coal and natural gas.[339]

It is important that the materials used in new renewable energy infrastructure can be recovered when these capital goods reach the end of their lifetime. Strategies to ensure that the renewable energy transition is also sustainable in the long-run are to **design for the future**, in particular design for repairability and recyclability. For existing capacity, **preserving and extending what's already made** by maximising product lifetimes, repairability and **using waste as a resource** to ensure that the materials in the current generation of renewable energy capacity can be reused.

Finally, scarcity of rare earth metals may prompt companies to **rethink their business model**, to ensure that they retain ownership over their assets and can recover them when they reach the end of their lifetime.

8B.GREENHOUSE GAS MITIGATION POTENTIAL

Undefined. The carbon footprint of producing all the renewable energy capacity that is required under a 2-degree scenario is only 6% of a continued reliance on fossil fuels.

However, the carbon footprint of producing renewable energy materials is still substantial. Estimates indicate that emissions from the production and operation of renewable energy and storage technologies will be about **16 billion tonnes CO_2e up to 2050**. Aluminium, graphite, and nickel production for energy technologies account for a cumulative 1.4 billion tonnes CO_2e up to 2050, when producing the equipment required for a 2-degree scenario.[340]

Mitigating these emissions over the full lifecycle of the renewable energy generation and storage capacity is the scope of this intervention. To our knowledge a quantification of the mitigation potential of applying circular economy principles to the renewable energy production and storage capacity is not available.

8C.BUSINESS CASE POTENTIAL

High. Many advanced and profitable engineering applications—including clean energy production and storage technologies, communication systems, computing applications, wind turbines and solar panels—use rare earth elements and technology critical elements. Current mining capacity doesn't meet the growing demand, so the potential for the recycling of those metals and minerals is significant. Urban mining (the process of reclaiming metals from waste products, for example, electrical and electronic equipment), batteries and e-waste recycling can be strategically explored in many GEF target countries, alongside upstream mining and bioleaching.[3415]

8D.CO-BENEFITS

This intervention targets the long-term since many countries are rapidly building up their renewable energy capacity, which is still far from reaching the end of its lifetime. It is estimated that China alone will generate 500,000 tonnes of used lithium-ion batteries and that by 2030, the worldwide number will hit 2 million tonnes per year.[342] However, there are already initiatives that aim to improve the recovery of valuable materials from dismantled renewable energy infrastructure, and therefore some of the co-benefits manifest themselves already now at a smaller scale.

Closing the loop on the materials needed to meet our renewable energy capacity reduces primary extraction and **protects ecosystems** where mining activities would otherwise take place.

In addition, material efficiency and recovery is a **prerequisite for a successful renewable energy transition**. The demand for critical metals, which are required for the energy transition, will soon exceed global production. Continued exponential growth in renewable energy capacity is not possible with present-day technologies and annual metal production. This applies, for example, to the indium required for solar panels, the tellurium and cadmium for highly efficient solar panels and the neodymium used for permanent magnets in wind turbines and electric vehicles.[343]

8E. BARRIERS

Economic and financial. The recycling of metals like chromium, cobalt, niobium, palladium, platinum and rhodium is reaching 50%, but financial barriers remain which prevent higher recycling rates. The recycling rates of certain rare-earth metals are still below 1%. Barriers to making recycling financially feasible are that the concentration of metals in the products that are to be recycled is often low, the total volumes available for recycling are too low and many countries lack take-back infrastructure.[344]

Technological. Low-carbon technologies, particularly solar photovoltaic (PV), wind, and geothermal, are more mineral intensive relative to fossil fuel technologies. Because of the material intensity of low-carbon technologies, any potential shortages in mineral supply could impact the speed and scale at which certain technologies may be deployed globally.[345]

Low- and middle-income countries often lack the capacity to process rare earth metals. The recycling industries for end-of-life renewable energy equipment are mostly found in the EU and North America.

Looking at recycling of lithium-ion batteries from electric vehicles there are numerous improvements to be made to increase the scale and economic efficiency of the process. Better sorting, disassembly and separating of electrode materials need to be invested in and introduced as well as design for recyclability.[346]

Cultural. Companies and governments have a planning horizon which does not go beyond the lifetime of most renewable energy capacity.

8F. ENABLING CONDITIONS

An important driver for the circular design of renewable energy capacity is that already now the rare earth metals required are increasingly scarce. There is also competition between industries for these resources since electric vehicles, solar and wind capacity require partly the same materials.

This scarcity is aggravated by the fact that the market for rare earth metals is dominated by only a few countries. The primary supply chain of critical metals like neodymium, praseodymium and dysprosium runs mainly through China.[347]

With the energy transition demanding increasing volumes of these materials, scarcity will likely increase. That could drive these companies into **alternative business models**, whereby they remain the owner of the assets and can secure access to these materials in the long run. This also drives interests in urban mining and efficiency improvements in primary resource extraction.

Land use titles and concessions for renewable energy capacity can be tied to lifetime requirements. In the Netherlands, newly installed offshore wind power capacity needs to be built to last at least 40 years.[348]

Policy measures are needed that encourage energy efficiency, environmentally and socially sound practices, and innovation to ensure that clean energy technologies can be safely and efficiently dissembled and recycled.[343]

Current lithium-ion battery design implies the use of adhesives, bonding methods and fixtures that, at the end of use, require shredding or milling, followed by sorting. This causes component contamination and reduces the value of material streams.[350] For high-value recycling, the purity of recovered materials is required, which benefits from an analysis of the cell component chemistries, and the state of charge and health of the cells before disassembly. At present, this separation has only been performed at a laboratory scale. It requires manual disassembly methods with high job creation potential.

The 'system performance' of the battery recycling industry will be strongly affected by a range of factors, including collection, transportation, storage and logistics at the end-of-life. As these vary between regions, different jurisdictions may arrive at different solutions. Research, such as the Norwegian Research Council project,[351] which aims to understand the political economy of metals such as cobalt for green technologies and the impact of obtaining those metals on environmental decline and political conflict, might enable emergence of more circular practices in the mining sector.

Greening the power sector and battery production requires that upstream and downstream emissions-related challenges from clean energy technologies be meaningfully addressed through policy and innovation while integrating these emissions reductions into countries' NDCs under the Paris Agreement.[352]

CASE STUDY EXAMPLE: CRADLE-TO-CRADLE CERTIFIED SOLAR PANELS

SoliTek from Lithuania adopted circular design and business models for solar panels

SoliTek from Lithuania achieved the highest Silver level of Cradle-to-Cradle certification with its flagship SOLID series solar panels, which are manufactured using a mix of solar and geothermal energy. The company is able to recycle the majority of the waste generated during manufacturing. Next to this, the company is a partner in the Innovation Action project Circusol, developing circular business models for solar panels and assessing the capacity for second-life re-use of solar panels and their components.[353] Their research and development efforts to become more sustainable and develop new business models are supported by the EU research programme Horizon 2020.[354]

INTERVENTION 9. ECO-INNOVATION IN INDUSTRIAL CLUSTERS AND INFORMAL NETWORKS

Apply industrial symbiosis approaches to industrial parks and create both formal and informal networks to encourage the use of secondary resources across industries.

Sectoral scope	Heavy industry; Food processing; Manufacturing and assembly; Electricity generation
Synergy with GEF areas of operation	Climate change; Chemicals and waste; International waters
IPCC categories targeted	2 Industrial processes and product use 4A Solid waste disposal 4D Wastewater treatment and discharge

9A. STRATEGY DESCRIPTION

Collaborating to create joint value is important for industrial symbiosis, where **waste is used as a resource**. In some cases, the suppliers to industries, or producers of consumer goods and capital equipment, may have the opportunity to **rethink their business models** and consider opportunities to create greater value and align incentives that build on the interaction between products and services. Examples are peer-to-peer sharing between businesses to improve the utilization rate of capital goods and chemical leasing, whereby chemicals are offered as a service rather than sold. In a sales model, the supplier is incentivised to maximise the sales volume, while in a leasing structure they are incentivised to provide a chemical service while using the least amount of chemicals.[355]

Incorporating digital technology can support industrial symbiosis. An example is the SymbioSys tool, which is a database for companies to help them identify opportunities for material substitution and exchange. It allows for the visualisation of synergies, exchange of resources and joint waste management opportunities and has been tested by 25 small and medium enterprises (SMEs) in Northern Spain.[356]

The circular economy potential of collaboration along and across industrial value chains is not limited to large industrial enterprises but also applies to the informal sector and micro, small and medium enterprises (MSMEs). In Sub-Saharan Africa, the informal sector contributes 72% of employment, while it contributes 65% in Asia and 51% in Latin America.

The strategy here supports the drive in informal networks by removing barriers to innovation[357] and providing them with access to circular economy concepts and technologies. These include, for example, additive manufacturing (3D printing), online marketplaces for secondary products and materials and using waste as a resource, connected with the skills and knowledge present in the informal sector.

9B. GREENHOUSE GAS MITIGATION POTENTIAL

97 to 108 billion tonnes CO_2e between 2020 and 2050. This value stems from the global mitigation potential of 128.8 to 143.8 billion tonnes CO_2e between 2020 and 2050, which combines strategies that improve and reduce material use, use waste as a resource, reduce emissions of refrigerants and improve energy efficiency.[358]

This global figure has been adjusted for the share of industrial GHG emissions that stem from non-OECD countries. This share is 75%.[359]

Over time, the share of non-OECD countries in global industrial GHG emissions is likely to increase. The global added value from industry and construction is around US$23.6 trillion, of which low- and middle-income countries provide 46%. However, their share is rising. In 2000, low- and middle-income countries were responsible for only 28%.[360]

9C. BUSINESS CASE POTENTIAL

Medium/high. The adoption of the eco-industrial parks (EIP) concept is growing. The number of parks increased from 50 to 250 between 2000 and 2018. According to the World Bank, EIPs offer the business advantages of traditional industrial parks while also using resources more efficiently, improving productivity, supporting firms in achieving their social responsibility goals, and lowering exposure to climate change risks.[361]

9D. CO-BENEFITS

There are several co-benefits of collaboration in industrial clusters and networks of workshops that produce or assemble consumer products and capital equipment. In addition to climate change mitigation, it helps reduce water use and thereby **safeguards freshwater resources**.[362] 19% of global water use stems from industries.[363] In addition, it prevents chemicals and waste from going to landfill. Where byproducts from processing forestry and food products are used, landfill GHG emissions from the disposal of organic waste are also reduced.

EIPs can be a supportive and enabling environment for entrepreneurship, investment, technological progress, the upgrading of skills, the creation of decent jobs and increased social mobility. EIPs can help countries benefit from access to global trade, and foreign direct investment.

Socio-economic benefits include improvements in **health and safety** where waste creation is avoided. Other benefits are that industrial activities concentrate on industrial parks, which improves monitoring and often allows for more professional **job opportunities** in waste collection and processing.[364] An example where informal waste collection was combined with informal waste collection is the Sustainable Recycling Industries programme,[365] which seeks colocation spaces for informal collectors and industrial parks. This is demonstrated by e-waste management in India, where informal waste collectors dismantle e-waste and sell recovered materials to buyers at industrial parks—sometimes even supported by online marketplaces.

So far, eco-innovation at industrial parks focuses mostly on reaping the benefits of collaboration within the premises of the park. The example of informal waste collection indicates that opportunities remain to further develop the relationship between consumers and producers through service models or take-back schemes.

9E.BARRIERS

Economic and financial. Industrial symbiosis creates strong ties between companies. This creates dependencies—and when companies relocate, new suppliers of raw materials need to be selected. A precondition for industrial symbiosis to work is that all parties benefit and have a common interest to maintain the exchange of materials and energy.

Legal, regulatory and institutional. Industrial parks are often developed to attract industries, while not considering the competitive advantage offered by clustering certain industries. Governments must take a design perspective to industrial clustering.

9F.ENABLING CONDITIONS

There are tools available on the Green Industry Platform to support the development, design, management and monitoring of EIPs.[366] To mobilise the private sector to become an active agent in the industry transformation, the GEF has established a Private Sector Engagement Strategy (PSES). PSES helps to facilitate multi-stakeholder platforms for sustainability based on strong in-country networks, and generate efficiencies that connect market demand with sustainable models of supply.[367]

Other enabling factors are the early definition of a business case for all participants, as well as legal requirements that improve the environmental performance of companies and reduce their waste volumes. Additionally, EIPs are more effective when they address both environmental and social issues, such as job creation, at the same time.

CASE STUDY EXAMPLE: EIP INITIATIVE FOR SUSTAINABLE INDUSTRIAL ZONES IN VIETNAM

The Vietnamese EIP initiative supported the adoption of industrial symbiosis in four industrial parks across Vietnam. Within the initiative, which was co-funded by the GEF, 18 industrial symbiosis opportunities were identified. After feasibility studies were completed, 12 were implemented.

At the beginning of the project, approximately 70% of effluent from industrial zones was directly discharged without prior treatment, causing severe pollution of surface and groundwater, and the marine ecosystems. Untreated solid waste with a high proportion of hazardous material was also on the rise in industrial zones. Fast-pace economic development depended on high consumption of natural gas, electricity and especially coal, resulting in a rapid increase in GHG emissions.[368]

The environmental benefits of implementing all 12 opportunities for industrial symbiosis would result in an annual GHG emissions reduction of 70,500 tonnes CO_2e, additionally saving 885,333 cubic metres of freshwater and reducing waste volumes by 84,444 tonnes per year. The payback time for each of these opportunities ranges between three months and eight years.

Furthermore, a total of around 1,000 options to further improve resource efficiency and prevent waste were identified. Of these, 546 were implemented, reducing electricity use by 19,274 megawatt hours per year, fossil fuels use by 142 terajoules per year, reducing GHG emissions by 30,570 tonnes CO_2e per year, reducing water usage by 488,653 cubic metres per year and reducing the use of chemicals and materials by 3,121 tonnes per year. Next to this, the interventions resulted in financial savings of €2.9 million per year, with an average payback time of seven to eight months.

INTERVENTION 10.
CIRCULAR DESIGN IN CONSTRUCTION

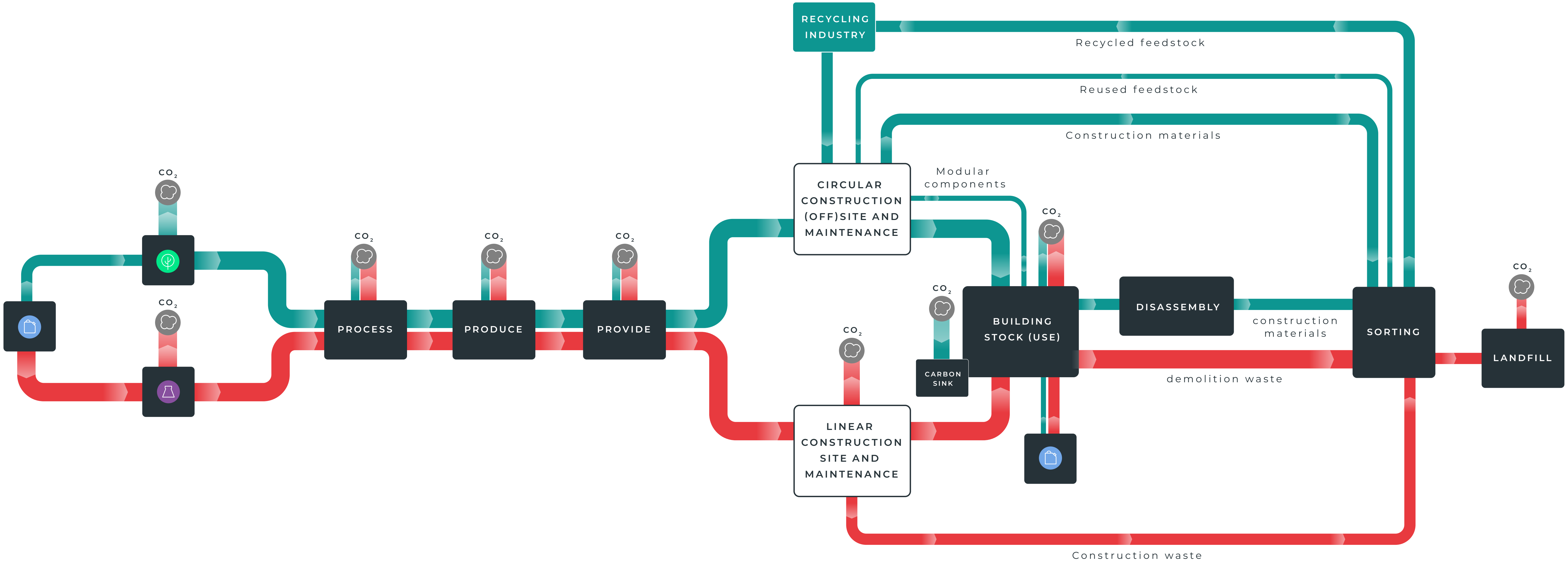
Design buildings to improve their energy efficiency, and minimise waste in the construction process by applying passive design and modular and offsite construction.

Sectoral scope	Built environment value chain
Synergy with GEF areas of operation	Sustainable cities impact programme; Climate change focal area strategy; Chemicals and waste
IPCC categories targeted	1A Fuel combustion activities / 1A2 Manufacturing industries and construction 2A Mineral industry 2B Chemical industry 2C Metal industry 3B Land 4A Solid waste disposal

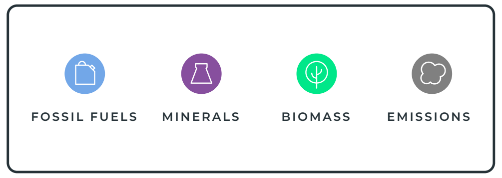
CIRCULAR DESIGN IN CONSTRUCTION

Optimising the design of buildings to minimise energy use at end-of-life, urban mining and substituting materials with high embodied emissions with bio-based materials can significantly mitigate GHG emissions and reduce virgin resource use.

Note that the flows in this graph are indicative only and aim to illustrate extreme opposite scenarios.



INPUTS & OUTPUTS



RESOURCE & EMISSIONS FLOWS

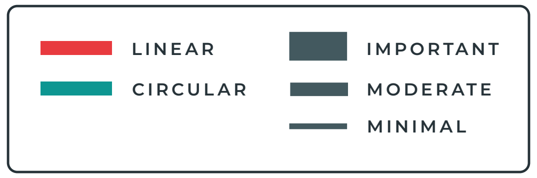


Figure 5. Value chain mapping in circular and linear scenarios.

10A. STRATEGY DESCRIPTION

Low- and middle-income countries are rapidly constructing the necessary infrastructure and building stock to meet the demands of a growing, and increasingly wealthy, population. This, however, increases resource extraction and emissions related to the production of building materials. Yet it presents a major opportunity to design buildings and infrastructure in a way that minimises energy use and emissions throughout their full life cycles.[369 370]

The built environment is responsible for over one-third of global energy consumption[371] and is a significant source of CO_2 emissions.[372] With the energy efficiency of buildings gradually improving, the environmental impact of the construction phase and the emissions embodied in construction materials becomes more prominent.[373 374] Cement production alone is responsible for 4% of global CO_2 emissions.[375]

This intervention focuses on **designing for the future**, where the design of buildings is optimised[376] to minimise energy use throughout the life cycle and allow for disassembly rather than demolition at the end of the lifetime. **Preserving and extending what's already made** and **using waste as a resource** also come into play, in the form of urban mining whereby secondary building materials are harvested. Although partly covered in the Intervention three on bio-based materials, design can also help **prioritise regenerative resources**, whereby the impact of materials with high embodied emissions can be reduced. Materials such as concrete are heavy contributors to the embodied emissions associated with the building stock. There are several alternative forms of concrete such as flashcrete,[377] hempcrete and timbercrete,[378] where renewable materials and recycled concrete[379] lower the impact of the material aggregate.

The interventions for circular design in construction target the whole life cycle of the building. For example, applying passive design principles to reduce the overall energy use of the building throughout its use phase, and to make use of its natural surroundings, including the application of green roofs. Green roofs use soil and vegetation as living insulation, thereby reducing the energy required for heating and air conditioning. Waste should also be minimised in the construction process, for example with offsite construction and modular design. The end-of-life value of buildings should be optimised through design for disassembly and modular design, and urban mining whereby demolition becomes disassembly and the design of new buildings incorporates building elements and materials from demolition sites should be incorporated.[380]

Biomimicry, the practise of looking to nature for inspiration to solve design problems in a regenerative way, can be applied to enhance building design.[381] Similarly, with the **incorporation of digital technology**, software can improve the design of a building, organise the construction process and limit waste. It can also help develop a database of materials and construction modules applied in buildings to ease their recovery at the end of their lifetimes.[382]

10B. GREENHOUSE GAS MITIGATION POTENTIAL

24 to 57 billion tonnes CO_2e from 2020 to 2050. Passive house design can reduce GHG emissions by around 0.5 tonnes CO_2e per person per year.[383] This figure has been applied to a global population of 7.8 billion, 90% of which live in non-OECD countries[384] and a period of 30 years between 2020 and 2050. As by 2050, the current floor space of the building stock of 223 billion square meters will almost double to 415 billion square meters,[385] around 46% of the global floor space by 2050 will be built in the coming 30 years. Assuming linear growth of this building stock, 50% of the potential of passive design can mature already before 2050. This estimate is conservative, as it does not account for population growth and growth in mitigation potential per capita if floor space per capita increases.

To make a global estimate for passive design, estimates for building design with proper insulation and high-performance glass have been added to the higher end of the range only. Although these can reduce global GHG emissions by 27 to 32 billion tonnes CO_2e between 2020 and 2050, it is unclear whether these are already included in the estimates for passive design. Green and cool roofs can reduce an additional 0.6 to 1.1 billion tonnes CO_2e between 2020 and 2050. These have also only been added to the higher end of the range.

Adopting more efficient production processes can reduce CO_2 emissions by 50 to 55% compared to conventional construction methods.[386] In Europe alone, reducing waste in construction with prefabrication, off-site construction, and 3D printing has the potential to reduce GHG emissions by 0.2 billion tonnes CO_2 per year.[387] These figures have not been included in the estimates above.

10C. BUSINESS CASE POTENTIAL

High. Passive design is seen as an important strategy to provide housing that is both affordable and efficient.[388] Passive building standards are stated to be at or near profitability for most new-build segments.[389] Offsite construction methods, modular design and design for disassembly are already implemented at scale, and have become increasingly competitive.[390 391] While insulation and green roofs are feasible, with the global savings far outweighing the costs, that is not yet the case for high-performance glass.[392]

The implementation of different circular design applications at scale (green roofs, smart thermostats, insulation and smart glass), which partially represent the full scope of this intervention, would require an investment of US$2.06 trillion worldwide, while saving US$26.94 trillion between 2020 and 2050.[393]

10D.CO-BENEFITS

Passive design improves **climate resilience** as it keeps indoor climates pleasant, even during periods of extreme heat, or when the power supply is disrupted.[394] This feature of passive design **reduces household expenditure** on energy services and helps **improve the trade balance** of countries which rely on imports for their energy needs.

The reduction of waste produced during construction also helps reduce the disposal of **chemicals and waste**. If waste remains, it is easier to carefully handle this waste during offsite construction in a manufacturing environment compared to waste produced at construction sites. A related co-benefit is that higher material efficiency during construction also reduces the volume of construction materials required, which reduces both GHG emissions and material use.

Offsite construction can also help improve **labour conditions and safety**, as it is easier to create a secure working environment in an assembly setting than on a construction site.[395 396] Next to this, the modular layout of the building can add flexibility in its use, but also retains a higher end-of-life value.[397 398]

10E.BARRIERS

Economic and financial. A barrier to improving the material efficiency of the construction sector is the low prices for construction materials. This is in part due to the fact that negative externalities are not priced or taxed. Negative externalities relate to the impact of primary extraction and GHG emissions from the production of carbon-intensive construction materials.

The end-of-life value of construction materials is low. Even when deploying modular design, financial institutions often lack the necessary understanding of circular business models to factor in a high end-of-life value in their mortgage lending.[399]

Legal, regulatory and institutional. A regulatory enabling framework that allows for offsite construction is often lacking.

Technological. Construction value chains with multiple actors are exceedingly complex, while buildings have long life cycles and multiple users with diverging interests, creating a technical barrier.[400] When a building reaches the end of its lifetime, there are additional technical barriers regarding the recovery of building materials, like bricks, especially when they are connected by Portland cement and reinforced concrete elements, or composite materials in general.[401]

Capacity limitations stem from the limited familiarity and adoption of circular economy design and collaboration tools, information and metrics. This includes design tools and guides detailing circular economy methods such as:[402] design for disassembly and design for adaptability, as well as a range of collaboration, building and material information tools and circularity metrics. These tools can help streamline the design and construction process and inspire a lifecycle approach. A building information model, for example, enables stakeholders along the value chain to collaborate more efficiently, which fosters optimised resource management and maintenance. More concretely, a building information model has the potential to foster reusability and recycling of materials by using the information provided by materials passports.[403 404]

Cultural. The construction sector is often organised in silos, which hampers collaboration across disciplines and organisations. In some cases, the sector is dominated by protecting vested interests, which is a barrier to innovation.[405 406]

10F.ENABLING CONDITIONS

Key enabling conditions for modular design, passive design and offsite construction are the available software tools that can facilitate collaboration in the design, construction and even disassembly processes.

Policymakers and development partners need a stronger evidence base to adopt circular principles in construction. This is important as governments have development partners and together have significant procurement power, which they can leverage by adopting circular procurement principles. When incorporating environmental considerations like passive design, modular design, waste volumes or the incorporation of recycled or reused building elements, procurement can select proposals with a lower environmental impact.

Other enablers are the adoption of standards and building codes that are essential to support the innovations needed at scale, as well as the effective adoption of design principles for the construction sector.[407]

CASE STUDY EXAMPLE: **THE ECOMO HOME**[408]

The ecomo home is a sustainable house built in South-Africa and designed for living in collaboration with nature.

Modular design and offsite construction makes the Ecomo Home low-maintenance and provides flexibility in the functionality and size of spaces. The house uses timber frame construction to prevent the use of carbon-intensive construction materials. By prefabricating the modules and assembling them on-site, waste can be minimised. The modular and flexible design allows the users of the building to adapt the design to changing requirements, which reduces costs during the lifetime of the building.

The carbon footprint of construction is 50 to 55% lower than when using conventional building materials and carrying out on-site construction. The application of each cubic metre of a timber frame can sequester an average of 0.8 to 0.9 tonnes CO_2e.

Barriers to the wider application of passive design, offsite and modular construction are low awareness and familiarity with design and collaboration tools, information and metrics that enable the application of circular economy principles.

CASE STUDY EXAMPLE: **EASTGATE CENTRE**[409]

Office and shopping complex constructed in Zimbabwe using green architecture and biomimicry principles.

The design of the Eastgate Centre mimics that of termite mounds, which have a design that allows air to be refreshed even in the deepest parts of the mound. Due to its passive design, the Eastgate Centre no longer requires a conventional air conditioning or heating system.

Overall, the centre uses less than 10% of the energy of a conventional building with a similar size and the lower energy bill saves considerable costs to the users of the building. Meanwhile, the absence of an air conditioning and heating system also enables the tenants to pay rent that is 20% lower than those in the surrounding buildings.

Even though the construction was a success, the higher upfront investment was considered to be a barrier for replication.

INTERVENTION 11.
NON-MOTORISED AND SHARED TRANSPORT

Prioritise non-motorised transport, vehicle sharing and public transport in urban development.

Sectoral scope	Built environment; Transport
Synergy with GEF areas of operation	Climate change; Sustainable cities
IPCC categories targeted	1A Fuel combustion activities from 1A3 Transport

11A. STRATEGY DESCRIPTION

The transport sector is responsible for nearly 10% of all emissions across Africa, South Asia, East Asia and the Pacific, Latin America, North Africa and the Middle East.[410] In addition, transport emissions are amongst the fastest-growing sources of GHG emissions. Between 2000 and 2016, transport emissions increased 23% globally—but by close to 50% in non-OECD countries. Growth was the largest in Asia, with an average 98% increase in CO_2 emissions from passenger and freight transport, largely due to a combination of population growth and increased motorisation.[411]

Modal shifts away from private car use and ownership is a promising strategy. Private passenger vehicles contribute 75% of passenger transport emissions yet public transport accounts for just 7% while covering one-fifth of global passenger transport. Railways account for 8% of global passenger transport while contributing only 3% of global transport emissions.[412]

In cities, the transport sector is also responsible for air pollution at levels which far exceed those considered safe by the World Health Organization.[413]

This intervention focuses on the **prioritisation of regenerative resources**, by creating space for walking and cycling, transport modalities that do not require fossil fuels and have a positive rather than negative health impact. The second approach is to **rethink the business model**, whereby vehicle sharing and public transport are preferred over underused, privately owned assets. Here, the **incorporation of digital technology** can help match supply and demand for mobility and thereby support an increase in vehicle utility rates, both in terms of reducing the time in which a vehicle stands idle and increasing the occupancy rate of all its seats. More specifically, this intervention targets: urban planning for walkable cities, investing in cycling infrastructure, rolling out public transit systems and promoting carpooling or car-sharing.

11B. GREENHOUSE GAS MITIGATION POTENTIAL

9.9 to 20 billion tonnes CO_2e between 2020 and 2050 for Asia, Latin America and Africa alone. The global mitigation potential for walkable cities, cycling infrastructure, public transit and carpooling is 19 to 40 billion tonnes CO_2e between 2020 and 2050.[414] This estimate is adjusted for the target region, whereby 51% of global transport emissions were from Asia, Latin America and Africa in 2016.[415]

The International Resource Panel estimates that if 25% of drivers shift to car-sharing, GHG emissions could be reduced by 10%. Shifting 25% of trips to shared rides would reduce emissions by 20%.[416]

11C. BUSINESS CASE POTENTIAL

High. Investments in walkable cities and public transit vary considerably across regions. However, when investing in cycling infrastructure, municipalities tend to save on investments in car infrastructure. When saving US$2030 trillion in car infrastructure to make way for bicycles, annual operational savings amount to 400 billion globally. For carpooling, the business case is evident as it requires no investment, but potentially saves US$186 million for just the US and Canada.

This positive return on investments in active or non-motorised transport modes is confirmed by the Ellen MacArthur Foundation, which estimates that the return on investment of improved cycling infrastructure in Amsterdam was 1.5:1. Similar estimates for Delhi and Bogotá arrived at returns of 20:1 and 7:1 respectively.[417]

The returns on investment go even further. Investing in active transport modalities improves air quality, and has health benefits due to the physical exercise involved. This saves healthcare costs. In Portugal these savings were estimated to be between €3.8 billion to €6.8 billion (US$4.6 billion to US$8.2 billion),[418] and in New Zealand between NZ$127 million and NZ$2.1 billion (US$91.2 million to US$1.5 billion).[419]

11D. CO-BENEFITS

The environmental benefits of shared, non-motorised and public transport are significant. Along with the reduction in GHG emissions,[420] lower fossil fuel use also improves **air quality**[421] which has major **health benefits**.[422] Improved vehicle utility through sharing also saves large amounts of **valuable urban space**[423] that unused vehicles would otherwise take up and that oversized infrastructure requires when cars transport less than their capacity.

There are also social benefits; improving the walkability of streets can **reduce urban crime**,[424] and an increased number of cyclists and pedestrians on the roads is linked to an increase in **road safety**.[425] Walkable cities also give residents greater opportunities for social interaction, enhancing their sense of community and, in doing so, individuals' health and happiness.[426]

11E. BARRIERS

Economic and financial. Interestingly, the economic and financial barrier for bicycle infrastructure is not that there is no funding available. On the contrary, allocating funds to public, shared or non-motorised transport often avails investments in expensive infrastructure for cars,[427] which requires a lot more space to both move and park.[428] Although an increasing number of municipalities see the importance of non-motorised transport for public health, safety and wellbeing, infrastructure for cycling and walking continue to receive only a small fraction of public funds spent on transportation. This only requires a different allocation of transport budgets,[429] and perhaps a shift in underlying political priorities.

Health, wellbeing and the safety benefits of the public stemming from shared or non-motorised transport are difficult to quantify in monetary terms. Existing studies on monetary benefits often have their origin in OECD countries and are not applicable to the GEF recipient countries.

Legal, regulatory and institutional. More emphasis can be placed on the configuration and layout of cities, as this predetermines mobility and has a significant influence on transport emissions. Laws on spatial planning are often outdated. Sometimes zoning building requirements or regulations on urban development in Global South cities have good intentions but derive from post-colonial models that restrict the kinds of neighbourhoods that can facilitate shared mobility.

Some municipalities are seeing trends in the other direction. Crime can deter people from choosing to walk or cycle[430] and, where air quality is low or hazardous, outdoor travel modes may also be deprioritised.[431] These trends exist even though a growing car fleet only aggravates these issues.

Technological. The technology for public, shared and non-motorised transport is available. Digital technology can help in matching supply and demand[432] and improve the overall occupancy rate of vehicles[433] or accessibility of public transport. Technology also offers opportunities. For example, if Google Maps nudged[434] users into choosing available alternatives to private car mobility. However, the key to reducing transport emissions and developing relevant co-benefits is not in improving car efficiency or the use of big data to steer traffic flows, but rather a modal shift, which faces habitual and cultural barriers.[435 436]

The knowledge to prioritise public, shared and non-motorised transport is available but overall government administration planning capacity in low- and middle-income countries is often insufficient.[437 438] There is also a strong push towards economic growth, which can be at odds with wellbeing and pro-poor development strategies; the choice between expensive or largely inaccessible modes of transport and low-cost alternatives, which are available to larger target groups.[439] Here, equity is crucial: cycling infrastructure tends to be extended to areas of privilege only.[440 441] Furthermore, large commercial project developers sometimes offer solutions that require big investments, but fail to consider people's interests and preferences. This leads to a bias for big highways and residential towers instead of considering public spaces, safety, accessibility and health.

Cultural. In some locations, cycling and walking are considered a risky endeavour as the traffic may not be used to cyclists, and using a car also makes one less vulnerable to street crime. However, there is clear evidence that with separate and dedicated cycling infrastructure, and increased numbers of cyclists, the risk of injuries actually goes down.[442]

Another cultural barrier is that people attach personal identity and status to material possessions such as cars,[443] which is often encouraged by marketing.

The covid-19 pandemic presents a further opportunity to demand more space for safe non-motorised transport and draw more attention to public health and resilience. In response, several municipalities have started investing in new infrastructure.[444]

11F. ENABLING CONDITIONS

A key enabler is political will and courage. In Bogotá, former mayor Enrique Peñalosa championed cycling infrastructure and introduced a bus rapid transit system at the expense of car lanes.[445 446] This also helped create alignment between different government bodies, residents and non-governmental organisations and interest groups. Additionally, the roll-out of public transport requires carefully balancing supply and demand, while its use should be effectively promoted.

CASE STUDY EXAMPLE: **RABAT-SALÉ TRAMWAY**

A public private partnership delivering a successful tramline in Morocco[447]

In 2007, the twin cities of Rabat and Salé in Morocco were connected by a tram line, which was operated by the Société du Tramway de Rabat Salé (STRS). The tram services approximately 110,000 passengers and provides more than 32 million trips a year. The tram operator employs 312 staff to run 22 trams. It recovers over 96% of the operational costs from ticket sales alone.

The Rabat-Salé Tramway changed people's perception of public transport. According to a poll, 77% of respondents reported that public transport is affordable. The tram is widely viewed as a success and was expanded to serve additional routes into the city and its surrounding areas.

The Rabat and Salé municipalities are struggling to densify the cities to reduce transport requirements and allow for effective public transport. An unsatisfactory bus system in the past encouraged the growth of the informal transport sector, which will remain there until there is a successful modern transportation system. That requires more than a tramway.However, the tramway is a good example of public transport that can exist and expand in tandem with an informal transport system.

Key enablers for the Rabat-Salé Tramway were political will, financing and operational tools such as public-private partnerships, which came together to create a viable opportunity for large-scale investment in transport. The financing for the tram is a fifty-fifty combination of government funding and international development loans. Repayment started five to seven years after the start of construction and the loans have a term of 20 to 25 years.

The 30-year concession agreement with Transdev from France to operate the tram system also played a role in its success. Enacted in 2011, the contract gave Transdev the responsibility for operating the tram, from ticket sales to wagon maintenance, and also required Transdev to provide training. In 2017 local engineers had already developed a strong sense of ownership over the tramline and rolling stock, part of which is assembled in Morocco.

INTERVENTION 12.
SHIFTING TO HEALTHIER AND MORE SUSTAINABLE DIETS

Shift to healthy diets that bridge the nutrition gap for lower-income brackets, while curbing meat consumption by diversifying diets to include more plant or insect-based proteins.

Sectoral scope	Agriculture; Land use
Synergy with GEF areas of operation	Climate change; Food systems, land use and restoration
IPCC categories targeted	3A Livestock 3A1 Enteric fermentation 3A2 Manure management

12A. STRATEGY DESCRIPTION

The livestock sector accounts for between 12 and 18% of global GHG emissions.[448] Global meat production and consumption have grown exponentially since the 1960s. Projections indicate that it will grow an additional 70 to 80% by 2050 due to increasing incomes and populations from developing and emerging economies.[449]

A healthy diet 'optimises health by ensuring an optimal caloric intake and consists largely of a diversity of plant-based foods, low amounts of animal source foods, more unsaturated than saturated fats and limited amounts of refined grains, highly processed foods and added sugars'.[450] It is also protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible and economically fair and affordable.[451] The transition towards such a diet will look different in different countries. Where high-income countries need to curb meat protein intake, for example, low-income countries may need to boost it to ensure optimal caloric levels.[452]

While high-income countries should take the lead in promoting dietary change, it is also important that low- and middle-income countries curb trends towards growing and excessive meat consumption. In these countries, it is crucial that meat consumption reaches healthy levels for groups whose minimum nutritional needs are not met.[453]

While there is growing willingness by governments to support more plant-based diets,[454] in particular because of their health benefits and ability to provide food security in the long run,[455] there are now also a growing number of international examples of governments that have successfully incentivised dietary shifts at scale.[456]

Dietary shifts are about improving the efficiency of agricultural commodities and thereby **prioritise regenerative resources**. Indeed, plant-based foods are less resource-intensive than animal-based foods[457] and as such, can be considered a more effective use of resources.[458]

Technical solutions to support the transition to more plant-based diets include plant- or lab-based alternatives to meat and dairy as well as insect-based proteins. However, shifting diets is a cultural issue first and foremost that will require greater education and awareness-raising efforts to inform and persuade consumers and producers to change the choices they make. Key levers of the transition are 1) evolving social norms, 2) minimising disruption, 3) selling compelling benefits and 4) maximising awareness.[459]

In regions where there is a calorie deficit and meat consumption is unlikely to increase dramatically in the coming years, the solutions in Interventions one and two to improve food productivity can play a crucial role instead.

12B. GREENHOUSE GAS MITIGATION POTENTIAL

15 to 166 billion tonnes CO_2e for the period 2020 to 2050. This estimate stems from the 2019 IPCC Special Report on Climate Change and Land, which estimated the global mitigation potential at 21 to 240 billion tonnes CO_2e.[460] It relies on a range of studies from 2009 to 2017, whereby the higher-end estimates are based on veganism, vegetarianism or very low ruminant meat consumption. The lower-end estimates are based on diets that involve moderate but not limited meat consumption.

The global estimate has been corrected for the share of livestock emissions from GEF countries of operation. For this correction, the country grouping of non-Annex 1 countries under the UNFCCC[461] has been used as a proxy for the GEF countries of operation. This proxy is imperfect since the non-Annex 1 countries exclude all EU Member States and several economies in transition. According to FAOSTAT, 69% of global livestock-related GHG emissions are from non-Annex-1 countries under the UNFCCC. The proxy is also imperfect as it disregards the trade of livestock products from Annex 1 to non-Annex 1 countries.

The global estimates from the IPCC can be compared to those from Project Drawdown for plant-rich diets: 65.01 to 91.72 billion tonnes CO_2e between 2020 and 2050.[462] These estimates are lower as Project Drawdown based its modelling on reduced quantities of meat rather than vegetarianism in regions where diets projected for 2050 exceed established health recommendations. According to Project Drawdown, different regions are modelled to require different 'shifts'.

The order of magnitudes are in line with sources stating that nearly 3 billion tonnes CO_2e per year could be mitigated through changes in diets and reductions in food waste in 2030 compared to a business-as-usual scenario, of which 75% would be due to dietary changes.[463]

The main contribution a shift to healthy diets makes to climate mitigation stems from the reduced demand for livestock farming from countries where there is an overconsumption of meat. This reduces associated emissions from enteric fermentation and prevents deforestation and land use change for agriculture.

12C. BUSINESS CASE POTENTIAL

Medium. The business case for shifting to plant-rich diets is difficult to estimate.[464] However, the relation to improved food security is strong. In addition, investing in more meat production is simply too costly. The need to improve the efficiency of food value chains by reducing meat consumption has already driven the Chinese government to push for a shift away from meat to ensure food security, for example.[465]

Traditional plant-based proteins such as lentils and other dried beans are typically cheaper than animal-based proteins.[466] However, as incomes rise, so does the intake of animal protein. Meat alternatives then serve a substitution purpose. Though their production costs are currently prohibitive for the mass market, they are falling very rapidly and have the potential to become less expensive than real meat.[467] Globally, the alternative protein market is expected to grow at a Compound Annual Growth Rate (CAGR) of 9.5% from 2019 to reach $17.9 billion by 2025.[468] Furthermore, meat production has been in decline for two years in a row.[469]

12D. CO-BENEFITS

Interviews indicate that the suggested dietary changes have multiple **health benefits**. They can improve food security and thereby reduce undernourishment. For high-income brackets, such diets can also reduce health issues related to the over-consumption of meat.[470] Excessive beef consumption can cause cancer, heart disease and obesity. Furthermore, insect-based proteins could potentially be significantly healthier than other conventional proteins. For low- and middle-income countries the food security argument is important, in particular when access to healthy, nutritious and diverse food is already limited.[471] What's more, reductions in intensive animal production—stemming from dietary changes—could significantly lessen air-pollution-related impacts affecting those living in proximity to animal farming operations. Agricultural emissions significantly contribute to the formation of particulate matter 2.5,[472] impacting respiratory function and causing cardiovascular illnesses.[473] Reducing agriculture-related ammonia emissions—largely attributable to livestock farming—could prevent as many as 200,000 deaths per year and have an economic benefit of several billion US dollars.[474]

Furthermore, investing in plant-based or insect-based proteins has lower costs than trying to meet growing demands for meat.[475] In addition, improved **animal welfare** is an important co-benefit, as industrial animal agriculture is characterised by its poor treatment of livestock.

Environmental arguments are mostly related to efficiency. Tapping into alternative protein sources in low- and middle-income countries can help prevent **land degradation** in countries with large herds. It also reduces **air pollution**, and as livestock require a lot of water, **enhances water security in freshwater systems**. Finally, it would help **preserve forest ecosystems**. Meat production requires vast quantities of soybean for feed, often imported from countries with high deforestation rates.[476]

12E. BARRIERS

Economic and financial. Agricultural subsidies act as a critical barrier. Although outside of the GEF target region, the US livestock industry benefits from price-distorting government subsidies. As a result, the price of animal protein far from reflects its true cost.[477]

Legal, regulatory and institutional. The meat industry tends to lobby against change. In meat-producing countries like Brazil, for example, the industry has a significant influence on policy making.[478]

Technological. Animal products are often recommended to meet protein needs because they provide dietary protein at a modest caloric load. Plant-based proteins do not perform as well, but novel meat alternatives that use soy or pea concentrates offer comparable benefits.[479] However, these are not a suitable solution for most lower-income countries, where livestock can be a crucial mechanism to ensure the livelihood of many smallholder farmers.[480] These novelties also take years and significant investment[481] and expertise to develop, which may be less available in lower income countries.

Cultural. This intervention is most closely related to cultural barriers. Food is strongly tied to people's identity and symbolises many characteristics: wealth, hospitality, and even masculinity.[482] Furthermore, when there are parts of the population that suffer from a lack of access to protein, it is hard to adopt policies that only target excessive consumption of meat. Finally, there is the 'meat paradox',[483] which refers to the cognitive dissonance of consumers who are aware of welfare issues in the meat industry but still choose to eat meat.

12F. ENABLING CONDITIONS

Policy measures and awareness-raising programmes to promote healthy and sustainable diets[484 485] are key enablers, as illustrated by the case studies in this chapter. Public food procurement policies in schools, hospitals, prisons and government offices, in particular, can play a crucial role in influencing consumer choices.[486] Public health policies could have a big impact, as the overconsumption of meat has been linked to an increased risk of diabetes[487] and other non-communicable diseases, and its production linked to serious air pollution.[488] Furthermore, framing the issue from a health angle tends to be more impactful and accepted than environmental arguments, as illustrated by the drastic shifts in lifestyle that occurred during the covid-19 pandemic, many of which have been advocated for decades by the environmental community.

A cultural enabler is that perceptions are changing. A carbon tax on beef, for example, is more realistic today than it was just a few years ago. There is also a synergy with prioritising local protein sources. Traditional cuisines in developing countries are often primarily plant-based[489] and traditional or culturally appropriate foods are considered a key aspect of a sustainable diet.[490] Meat alternatives that closely mimic the taste of meat such as the Impossible Burger or Beyond Meat have also risen in popularity[491] and are increasingly penetrating mainstream markets through partnerships with fast food giants such as Burger King[492] or McDonalds.[493]

Clearly, the availability of sufficient and affordable nutritious food and access to diverse food sources makes it easier to change diets. Finally, the labelling, naming and packaging of products is also an important enabler, as shown by the example of packaging unhealthy food products from Chile. Other strategies to nudge consumer behaviours,[494] both from a policy and a marketing perspective, are also crucial to shifting consumption.

CASE STUDY EXAMPLE: **PROMOTING DIETARY CHANGES FROM VARIOUS ANGLES**

Dietary guidelines, taxes and private sector initiatives to promote a reduction in meat consumption

In 2016, the Chinese government issued guidelines to reduce domestic meat consumption by 50% by 2030.[495] Of 2,000 Chinese people surveyed in 2018, 70% of respondents indicated that ‘meat reduction campaigns have made them more aware of the benefits of eating less meat’.[496] 13.8% reported eating less pork and 6.4% reported eating less poultry.[497]

Another example of a policy intervention aimed at changing diets comes from Chile, where the government has implemented advertising restrictions on unhealthy foods, front-of-package warning labels and a ban on junk food in schools. 18 months following the adoption of these regulations, consumption of sugar-sweetened drinks dropped by nearly 25%, while the sale of bottled water, diet soft drinks and fruit juices without added sugar increased.[498]

A private-sector example also comes from Chile. The Not Company sells plant-based meat alternatives as well as plant-based milk and ice creams. The company is valued at US$250 million, according to TechCrunch, and sells products in Chile, Argentina and Brazil.[499] According to the company founder, the Not Company has also already captured 10% of the (admittedly small) Chilean market for mayonnaise in just 8 months in stores.’[500]

Alternatives to animal products are a huge (and still growing) category for venture investors,[501] which has helped the Not Company **secure funding** to invest in their alternative meat technology. The Not Company positions themselves as a ‘tech company, not a food company’,[502] which may also help explain the funding they are able to attract from private equity firms, including Jeff Bezos’ personal investment firm.[503]

4. ACCELERATING **THE TRANSITION TO A LOW-CARBON CIRCULAR ECONOMY**

GREENHOUSE GAS MITIGATION POTENTIAL

The 12 interventions listed have a joint mitigation potential of between 285 billion tonnes CO_2e and 695 billion tonnes CO_2e between 2020 and 2050. With a remaining carbon budget of 580 billion tonnes CO_2e in a 1.5-degree scenario, or 800 billion tonnes CO_2e in a 1.75-degree scenario, circular greenhouse gas (GHG) mitigation is necessary to bring the global economy back on track to limit global warming to 1.5-degrees.[504] Discounting the years from 2018 to the end of 2020, with around 56 billion tonnes CO_2e emissions per year,[505] we only have a carbon budget of 633 billion tonnes CO_2e left for a 1.75-degree scenario by early 2021.

REAPING THE CO-BENEFITS

According to the UNEP's *Emissions Gap Report 2019*, 'There are multiple benefits from achieving climate change goals for other Sustainable Development Goals (SDGs), with these synergies being more pronounced than trade-offs, especially if the implementation is holistic and concurrent'.[506] Many of the SDGs relate to the adverse impacts of primary resource extraction and the disposal of waste to soils, water and air, including GHGs.[507] Since circular economy approaches to mitigating climate change also aim to reduce primary material extraction and waste disposal, the co-benefits are even more pronounced.

Environmental co-benefits include the preservation of ecosystems by reducing the extraction of resources and disposal of harmful waste, both as co-benefits of prioritising regenerative resources and developing the bio-based economy. By protecting the natural habitat of species, reducing water usage and moving away from monocropping into intercropping and agroforestry practices, biodiversity can be maintained and perhaps restored.

Socio-economic co-benefits range from increased agricultural and forestry production by increasing yields per hectare. Reducing food loss and waste can further improve food security. Other health benefits stem from the reduced air pollution in urban centres from transport interventions, the diversification of agricultural production which allows for more diverse diets and even personal wellbeing by using regenerative construction materials, like wood and bamboo, and relying on passive and biophilic design.

In addition, the circular economy promises economic growth. In China, for example, the Ellen MacArthur Foundation quantified that the circular economy could save businesses and households approximately ¥32 trillion (US$5.1 trillion) in 2030 and ¥70 trillion (US$11.2 trillion) in 2040 in spending on high-quality products and services, compared to China's current development path. These savings equal 14% and 16% of China's projected GDP in 2030 and 2040 respectively.[508] Although similar estimates of the economic benefits of the circular economy are underway for other countries, so far they are only available for the EU, China and India.

The circular economy is confirmed to be able to create valuable jobs, also in areas where there is a shortage of job opportunities, partly by focussing on local services[509] and materials. Furthermore, the quality of jobs can be improved by empowering the informal sector in the circular economy, and strengthening their role in the recovery and recycling of materials, production of new products and maintenance of existing products. Finally, the interventions proposed represent an opportunity to reduce income inequality by prioritising human resources, creativity and ingenuity over natural resources as a driver of economic development.

OVERCOMING BARRIERS

Identifiable barriers re-occurred throughout our different interventions. In relation to the l**egal, regulatory and institutional context**, the short-term planning horizon within government frequently emerged, which distracts from policy interventions with a more long-term impact. Another issue is the implementation of policies that do not account for possible knock-on effects and fail to address the root causes of issues. An example is a ban on using timber in Niger, which aimed at protecting trees from logging but when implemented the policy also discouraged people to plant new trees for future use. Finally, the informal sector often has an important role in low- and middle-income countries but is difficult to reach through policy.[510] Vested interests from industries lobbying against the adoption of environmental regulations is also a barrier to the adoption of effective legislation.

With **technological** barriers, we should distinguish between circular economy interventions that are low-tech, like composting, reducing food loss and waste, urban planning and regenerative agriculture or waste collection, and those that require internet access and more sophisticated technologies like urban farming or the production of cross-laminated timber. Certain technologies will disseminate slower in low- and middle-income countries where certain infrastructure is lacking or internet access is limited. Finally, the lack of awareness of the circular economy concept and lack of successful demonstration projects within the context where they can be scaled can be a barrier for the broader adoption of an intervention.

In addition, the impacts of circular economy interventions cross sectors and territorial boundaries and are therefore difficult to quantify or monitor. This hampers their justification, and makes attracting investments more difficult.[511]

Where circular economy solutions are low-tech, the necessary skills and technologies exist, but are missing the financial incentives, ability to mobilise early adopters and means to deploy them.

A knowledge barrier, which can also be perceived as a cultural barrier, is the misperception that issues need to be addressed in isolation and target the direct sources of emissions, rather than considering them in a system's context. This applies to all stakeholders in climate change mitigation. Another knowledge barrier is that in practice the end-users of circular products and services are sometimes poorly consulted. This is counter effective as they are the main adopters of the products and services. This is particularly prominent in urban planning but also in agroecology and developing environmental policies.

The short-term focus of policymakers and competition from more acute priorities like expanding the housing stock to accommodate a rapidly growing population prevail over long-term environmental priorities.
This was referred to as a **cultural** barrier. The short-term implementation time of some development programmes can also lead to failure if interventions require several years to be successfully implemented. In addition, it is important to inculcate a culture of data-driven decision making and collaboration across departments with different mandates. The siloed mandates of government bodies[512] or siloed structure of corporate entities is another barrier to the identification and implementation of circular economy opportunities.

Another cultural barrier is that personal success is commonly defined in material terms, as in the possession of consumer goods and the consumption of meat. This stands in the way of the adoption of service models and dietary changes. As disposable income goes up, so does waste and consumption—and this issue is especially prevalent in high-income countries, which provide a poor example.

An **economic and financial** barrier is the lead time for projects to bring in higher revenues—for example, regenerative agriculture or agroforestry. Such interventions take time to bring tangible results such as higher yields and revenues. Funders do not always have the patience needed to see such projects through. Furthermore, current accounting principles, approaches to risk estimation and mitigation put circular economy solutions at a disadvantage.[513]

In the current economic climate, incumbent technologies and approaches are more financially attractive. This could be because their negative externalities are not priced.[514] Without adequately pricing externalities, also the benefits of circular initiatives are insufficiently rewarded in monetary terms. That also affects the ability of circular innovators to access affordable funding.

Furthermore, it is difficult to incubate circular businesses and make them profitable, given that most non-circular-economy products are cheaper on the market. Local governments may not have sufficient authority to change market conditions and factor in the negative externalities of linear products. Although it is clear that we need to decouple material consumption from well-being, it is challenging to actually get companies on board given that a reduction in material consumption could mean a reduction in sales.[515] Although there are alternative business models available, business models that rely on sales can be deeply ingrained into corporate culture.

Multilateral development banks also face challenges in financing circular economy activities at scale. These include a reactive and risk-averse approach to financing. A second issue is that multilateral development banks often have the mandate to work with national agencies, while the circular economy asks for smaller-scale funding for subnational or municipal projects. In general, traditional project-based finance is less suitable for the systemic and multi-stakeholder approaches that the circular economy requires.[516]

ENABLING CONDITIONS

An enabling condition frequently repeated by experts interviewed within this project was that the circular economy's benefits should be made clear to decision-makers. Agricultural projects bolstered by demonstration projects that show what certain interventions could achieve, for example, helped to spark the confidence farmers needed to follow in the footsteps of the pioneer. If a solution is functional and successful, people will adopt it. Also at a government level, communication on the benefits is very important to create the willingness to adjust policies, whereby policymakers are more willing to act on positive impacts in the short run.

Furthermore, various government bodies and levels will have to collaborate to be able to act effectively on the cross-sectoral nature of circular economy opportunities. National and subnational governments should show leadership and an ability to convene stakeholders and leverage circular public procurement. Successful pilots can be scaled through peer-to-peer exchange between local governments, as observed in the ICLEI network.[517]

Connecting circular economy interventions with an immediate political priority, like job creation or reducing the emission and disposal of pollutants, is a clear enabler for the adoption of effective policies. While supporting legislation is a clear driver for action, lacking enforcement of that legislation, for example on responsible forest management, can significantly dilute the potential policy impact. Involving and consulting stakeholders in the policy making process, but also tailoring the circular economy interventions to a specific context, can further prevent policies from having a counterproductive effect. This could be matched by efforts to raise awareness and provide education and training, addressing misperceptions about a certain intervention. Solutions proposed should be all-encompassing, consider the full value chain to prevent issues from spilling over to other parts of the value chain,[518] and take technologies, procurement channels and enabling factors into account.[519] In some cases this may require taking interventions together, for example when considering regenerative agriculture, the bio-based economy and reducing food loss and waste.

Where industries or sectors rely on informal workers, the organisation, formalisation and in some cases also attaching public recognition or status to a certain job, have been proven to address waste management issues. Micro, small and medium-sized enterprises, on the other hand, can play a pivotal role in experimenting with and testing innovations in different contexts. Allowing for that experimentation and learning to happen necessitates supporting small, grassroots, decentralised and community-based initiatives. This could enable larger scale but well-informed programmatic approaches later on. Financial incentives can aid the adoption of circular interventions, for example, to cover the incremental costs between the conventional technology and the circular alternative.

Finally, data and insights on the drawbacks of the linear economy and the advantages of the circular alternative are important. Robust data collection and analysis systems can provide detailed data on resource flows, and feed them into reporting systems, building information on materials consumption and related impacts.[520] These systems could also identify circular economy opportunities, while transparency and openness on primary resource extraction from finite sources, GHG emissions and waste data can help put more pressure on companies to change course.

5. RECOMMENDATIONS

This paper clearly illustrates the role of the circular economy in mitigating climate change, while providing both socio-economic and wider environmental benefits. The previous chapter (Chapter Four) provides a summary of our interventions' greenhouse gas (GHG) mitigation potential, co-benefits and how to overcome the potential barriers in place for their realisation. This chapter seeks to provide solid recommendations for implementing circular projects with strong GHG mitigation potential.

STRUCTURING A CIRCULAR PROJECT

The GEF is already very well-positioned to use circular economy principles as a means towards reducing finite resource extraction and waste disposal. Being organised along themes that cut across sectors and industries as the circular economy does,[521] the GEF is already dedicated to supporting recipient countries with 'breaking down institutional and national silos, and developing integrated and innovative policy tools to leverage resources for environmental protection, including from the private sector.'[522] The GEF also often takes a regional or value chain perspective, which supports its ambition to 'to respond to global challenges at the systemic level and leverage resources that would not otherwise be available.' The GEF is already operating at the level we need to see for systemic change, surpassing the incremental changes which for a long time have characterised our global climate mitigation efforts.

1. **Combine policy interventions with project support**. Policies can become barriers in themselves to circular economy opportunities. Policymakers should have access to the macro-economic modelling that provides insight on the impact of creating the appropriate fiscal conditions for the adoption and scaling of circular economy interventions, such as abolishing subsidies on fossil fuels and introducing carbon taxes, levies on water extraction, tipping fees or duties on the import of carbon-intensive products.

2. **Consult and involve stakeholders**. To adequately consider end-user interests in circular economy solutions, we need stakeholder involvement. From engaging stakeholder consultants in policies that aim to address the use or disposal of single-use plastics, to the integration of indigenous knowledge in natural asset management. Anticipating demographic changes and economic development is also crucial, especially considering how these shifts will impact lifestyles.

3. **Prevent negative rebounds**. It is paramount that negative rebounds of efficiency gains are prevented. Experience with improving the energy efficiency of appliances shows that it results in increases in use, for example, partly offsetting the energy efficiency gains.[526] Both stakeholder involvement in developing the appropriate legal context for circular economy opportunities, and combining policies with project support are important ways to prevent rebounds.

4. **Apply systemic levers for change**. Focus often remains on making existing assets or incumbent industries, with their high and verifiable historical GHG emissions baseline, more efficient, rather than exploring truly sustainable—and perhaps even zero-carbon or carbon-negative—alternatives. Doing so will require a systems approach that aims to reduce negative impacts across the value chains involved in an intervention, such as regenerative farming.[527] It also helps to

identify collaborative strategies to develop a circular economy, in line with national objectives to safeguard natural assets, avoid waste creation and reduce GHG emissions all in parallel.[528 529]

5. **Cut across national borders and consider embedded emissions**. The sources of GHG emissions are commonly taken as the starting point for interventions. However, this fails to take into account emissions that are embodied in products that cross over borders—which accounts for 20 to 30% of global GHG emissions. This could create a bias for interventions that target incumbent entities with a high emissions baseline, with investments that help improve their efficiency, as opposed to systemic transformation.[530]

6. **Create a low-carbon lock-in**. Core levers and drivers for low-carbon development must be identified and targeted. For developing countries, this implies identifying opportunities to build vital infrastructure while minimising GHG emissions during construction and creating low-carbon lock-in for the future.

7. **Prioritise local produce**. Emissions from international transport are rising, so it is important to keep transport distances short. Besides bypassing emissions, prioritising local products can also make it easier to take a systemic approach in which all stakeholders, including those who benefit, and those who may not, have a say in the design of the project. It, therefore, safeguards against approaches where the benefits are geographically separated from potential negative socio-economic and environmental impacts.

8. **Demonstrate impact**. Metrics to demonstrate circular impact can be lacking, but they are vital to report on the broad range of circular economy project benefits. The wealth of methodologies available under the CDM and IPCC that estimate GHG mitigation and sequestration impacts at project level inadequately address circular economy opportunities. Under the CDM, the entity where the reduction takes place is often also the entity where the intervention takes place. In the circular economy, however, that is not always the case—the reduced application of carbon-intensive materials by a project developer leverages reductions in emissions for the production of materials, for example. Such value chain dynamics should become an integral part of estimating mitigation or sequestration impacts at the project level. This could take the form of socio-economic indicators, such as for job creation, health and poverty alleviation.[532 533]

9. **Target and involve micro, small and medium-sized enterprises (MSMEs) and the informal sector**. MSMEs provide a large share of the jobs in low- and middle-income countries but receive little political priority. Instead of attracting foreign investment for large scale operations, countries could invest in upgrading and greening informal production systems and providing them with proper infrastructure and training, while projects could target them through microfinancing and capacity building. Another advantage of targeting MSMEs is that they rely on the voluntary adoption of circular business models, which reduces the risk of public opposition that some large-scale, and often foreign-owned, investments may face. Projects can also formalise the role of informal workers, which can represent a large share of the labour force and marginalised groups, to ensure that the benefits of circular interventions reach all parts of society, as well as improve their position, labour conditions and perhaps even social status.

10. **Address the finance barrier**. Support the leveraging of private sector finance by adopting circular procurement principles in procurement process and by developing cooperative and blended finance mechanisms to support and de-risk early investment in circular economy initiatives.[534] Financing should target demonstration projects and their upscaling, including the private sector with its MSMEs, philanthropies and foundations.

11. **Involve the donor countries**. The circular economy requires collaboration, involving the demand-side and addressing the excessive material consumption that exists there. Consumers in the GEF donor countries are the end-users of some of the products whose value chains are partly in GEF recipient countries. For these value chains, international cooperation is necessary to effectively address environmental and socio-economic challenges. Examples are palm oil value chains, cocoa but also electronics.

12. **Involve the private sector**. The circular economy is an attractive entry-point to the private sector, especially through its ability to maintain material value along product value chains. The GEF can use the circular economy as a guiding principle in its collaboration with the private sector, while staying away from negative rebounds or business models and marketing strategies which rely on increasing material output, instead of delivering a high service level with stable or even decreasing levels of resource use.

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