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Mitigation benefits and co-benefits of policies, practices and actions for enhancing mitigation ambition: implementation of circular economies with a focus on waste-to-energy technologies and on industrial waste reuse and prevention solutions

Technical paper by the secretariat

Summary

This paper has been prepared in response to a request of the Conference of the Parties at its twenty-first session. It is based on a review of the expert literature on the subject, as well as on the presentations and discussions that took place during the technical expert meetings held in 2018 under the technical examination process on mitigation.

The information is structured with the help of the questions from the Talanoa Dialogue, with a focus on waste-to-energy technologies and on supply chain redesign and industrial waste reuse and prevention solutions. Both solutions are essential for the transition to a circular economy.

From the analysis of lessons learned on enabling factors, the following barriers and success factors, key actions and strategies emerge to enhance and scale up current efforts towards achieving the mitigation potential:

- Improve knowledge on waste quantities and characterization, improve metrics in order to improve management and increase transfer of technology. This in turn will increase investor confidence and technology development and transfer;
- Invest in market development for energy and by-products from waste-to-energy technology. Invest in awareness-raising and demand-side solutions. Changing consumption patterns will shape the future economy;
- Work on developing and adapting technology. Some technologies need scaling down before they can be rolled out. Other technologies need upstream and downstream development for ensuring cleaner waste streams at feedstock or planning for repairs at the design stage;
- Introduce a mix of policy instruments to support circular economy strategies and technologies to ensure predictability for investors and coherent frameworks across all policy areas, including waste management, renewable energy, materials extraction and fiscal policy;
- Align financing with needs, especially by providing patient finance and guarantees for high risk and innovative investments;
- Associate technical innovation with innovative business models and financing mechanisms. Focusing on key performance indicators in contracts, looking for symbiosis and testing cooperative finance mechanisms are a few examples that have been successful in promoting the transition to a circular economy.

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I. Background

A. Mandates

1. The Conference of the Parties (COP), at its twenty-first session, resolved to strengthen the existing technical examination process on mitigation[1] and requested the secretariat to organize the process and disseminate its results, including by:[2]

(a) Organizing, in consultation with the Technology Executive Committee and relevant expert organizations, regular technical expert meetings (TEMs) focusing on specific policies, practices and actions that represent best practices and that have the potential to be scalable and replicable;

(b) Updating, on an annual basis, following the meetings and in time to serve as input to the summary for policymakers, a technical paper on the mitigation benefits and co-benefits of policies, practices and actions for enhancing mitigation ambition, as well as on options for supporting their implementation.

2. COP 23 concluded the assessment of the technical examination processes, suggesting key ways to improve their effectiveness:[3]

(a) Better integrate the technical examination processes with the Marrakech Partnership for Global Climate Action;

(b) Focus on specific policy options and opportunities that are actionable in the short term, including those with sustainable development co-benefits;

(c) Engage expert organizations to organize the relevant TEMs;

(d) Engage Parties and non-Party stakeholders to organize regional TEMs, building on existing regional climate action events;

(e) Make the TEMs more interactive, provide an agenda and guiding questions well in advance and conclude the TEMs with a session on proposing ways forward and necessary actions;

(f) Provide input to the summary for policymakers, the high-level events and the Talanoa Dialogue.

3. The high-level champions, in consultation with the Technology Executive Committee and the Climate Technology Centre and Network, identified the following topic for the technical examination process on mitigation for 2018 in response to a request by the COP at its twenty-third session:[4] Industry implementation of circular economies and industrial waste reuse and prevention solutions.

4. This paper has been prepared in response to a request by the COP as referred to in paragraph 1 above and covers mitigation benefits and co-benefits of policies, practices and actions in relation to the implementation of circular economies with a focus on waste-to-energy technologies and on industrial waste reuse and prevention solutions. The paper also includes an exploration into options for enhancing their mitigation ambition and supporting their implementation.

B. Objective

5. The main objective of this paper is to compile and share information on the mitigation benefits and co-benefits of policies, practices and actions relating to circular economy activities with a focus on waste to energy, supply chain redesign, and industrial waste reuse

[1] Decision 1/CP.21, paragraph 109.
[2] Decision 1/CP.21, paragraph 111.
[3] Decision 13/CP.23.
[4] Decision 13/CP.23, paragraph 3.

and prevention solutions. The sharing of experience and lessons learned from implementing good policy options, practices and actions is intended to support Parties and non-Party stakeholders in facilitating the enhanced implementation of policies, practices and actions relating to the circular economy activities identified and discussed during the technical examination process. In addition, the paper includes options and strategies for scaling up or replicating good policy options and practices on circular economy activities that can enhance the mitigation ambition of pre-2020 action and support the achievement of the Sustainable Development Goals.

6. This paper is based on information provided at the global and regional TEMs on mitigation that took place during (1) the forty-eighth sessions of the subsidiary bodies, from 1 to 2 May 2018 in Bonn, Germany; (2) the Africa Climate Week, on 13 August 2018 in Nairobi, Kenya; (3) the Asia Pacific Climate Week, on 12 July 2018 in Singapore; and (4) the Latin America and Caribbean Climate Week, on 23 August 2018 in Montevideo, Uruguay.[5] It draws on presentations and discussions that took place during these TEMs and from sources of relevant information in the literature.

7. The information presented in this paper does not imply consensus among Parties on any of the issues or subjects discussed within the context of TEMs. The paper serves as a summary of the discussions that took place in the context of TEMs that are supplemented by appropriate information from the expert literature.

C. Structure

8. The report is structured in accordance with the three guiding questions from the Talanoa Dialogue. The Talanoa Dialogue, launched at COP 23, aims at collectively assessing the progress made on climate action and increasing action to reach the Paris Agreement goals. In order for stakeholders to be able to share their inputs, the secretariat has launched an online platform on which participants can submit their inputs addressing three main questions: Where are we, where do we want to go and how do we get there. The goal is to take stock of the collective efforts of Parties in relation to progress towards the long-term goal set out in Article 2 of the Paris Agreement and to inform the preparation of nationally determined contributions pursuant to Article 4, paragraph 8, of the Paris Agreement. The TEMs events are part of the technical examination process on mitigation and are designed around the three guiding questions mentioned above. The outcomes of the TEMs provide quality input to the dialogue.

9. Chapter 2 answers the question "Where are we?". After introducing the two main focuses of the paper, which are (1) waste to energy and (2) supply chain redesign and industrial waste reuse and prevention, the subchapters present case studies and analyse case-based information to describe the status quo of the two focuses. Chapter 2 includes a discussion of the status quo on a global level to help explain the global scale of the issues and the focuses of the paper. The chapter also focuses on current international and regional initiatives undertaken to tackle the main issues in the focus areas.

10. Chapter 3 answers the question "Where do we want to go?" by extracting lessons learned in terms of success factors and barriers in the status quo. Special attention is given to the mitigation potential and the environmental, social and economic co-benefits of the circular economy technologies and strategies in focus.

11. Chapter 4 answers the question "How do we get there?" by providing a strategy and by listing key short-term actions for various stakeholders who are drivers in the sector.

5 Detailed information on the global and regional TEMs held in 2018 is available at https://unfccc.int/topics/mitigation/workstreams/technical-examination-process-on-mitigation#eq-2.

II. Where are we?

A. Introduction

12. Circular economy is an alternative to a traditional linear economy (make, use and dispose) in which resources are kept for as long as possible by extracting the maximum value from them while in use, then recovering and regenerating products and materials at the end of each service life. Thus, waste and resource use are minimized, and when a product reaches the end of its life it is used again to create further value. This can bring major economic benefits, contributing to innovation, growth and job creation. Moreover, the circular economy could play a significant role in achieving the goals set out in the Paris Agreement. It is estimated that circular economy measures could reduce 33 per cent of the carbon dioxide emissions embedded in products and could reduce the current emission gap by half.[6]

13. A 2016 report by Circle Economy and Ecofys indicates that the most important contribution from circular economy measures to climate action is both energetic and material resource efficiency, which will lead to emission reductions throughout the entire value chain. Also, the Technical Executive Committee (TEC) published a policy brief, *Industrial Energy and Material Efficiency in Emission-Intensive Sectors*, which outlines challenges and needs, presents best practices and lessons learned, and provides recommendations for further action for energy and material efficiency improvements in industry.[7] Out of all emissions worldwide, half are related to materials. There are possibilities for reusing and recycling materials, as this can reduce the greenhouse gas (GHG) emissions associated with the production of basic materials. Reducing the emissions related to materials by 20–30 per cent using circular economy strategies will contribute to limiting the increase in global average temperatures to 1.5 °C above pre-industrial levels. Using recycled materials results in a sizeable reduction in energy demand requirements.

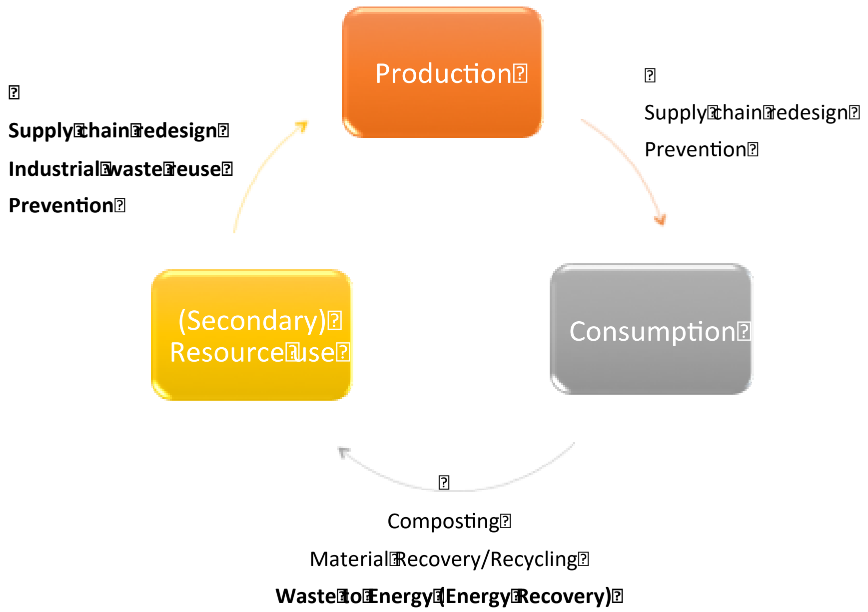
14. The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible and the generation of waste is minimized, is essential to ensure a low-carbon and resource-efficient pathway to sustainable development. This approach means looking at all options of the resource extraction, production, consumption and waste management chain to close the loop.

15. This paper includes more detail on two mitigation strategies within the circular economy concept, namely (1) waste to energy and (2) supply chain redesign and industrial waste reuse and prevention (see figure 1). Waste to energy is a group of technologies belonging to the waste management element of the circular economy depicted above. Supply chain redesign and prevention are strategies that run through all the resource use production elements of the circular economy, while industrial waste reuse has a greater focus on the material flows between resource use and production.

[6] See https://ieep.eu/news/what-role-can-circular-economy-play-in-delivering-the-paris-agreement.

[7] Available at http://unfccc.int/ttclear/tec/brief11.html.

Figure 1
Identifying waste to energy, supply chain redesign, industrial waste reuse and prevention in the circular economy



16. While efforts to prevent waste generation, and thus interventions in the production and consumption patterns, are preferable to end-of-pipe solutions to treat generated waste, both are necessary to transition to a circular economy. A current challenge is reviewing policies created for the linear economy with the circular economy in mind and creating incentives that support the different strategies within the circular economy framework.

B. Waste to energy

17. Waste to energy is the process of generating energy in the form of electricity or heat from the primary treatment of waste. It is a form of energy recovery. Waste-to-energy technologies consist of any waste treatment process that creates energy from a waste source. A number of new market technologies, such as anaerobic digestion, pyrolysis and gasification, are in the process of being deployed. These technologies provide the potential to recover products from the waste stream, which complete incineration would not allow (Malinauskaite et al., 2017).

18. Waste-to-energy technologies are available for agricultural waste streams, industrial waste streams and municipal solid waste (MSW). These solutions are preferable to disposing of waste, as they are providing an alternative source of energy for communities, and they considerably reduce or render inert the residues.

19. Table 1 summarizes the main categories of waste-to-energy technologies currently available. Within each group is a wide variety of technology providers that each offers a specific solution. The table also considers the type of waste stream required for each technology, the typical intake capacity of a unit and estimated typical capital investment cost.

Table 1
Inventory of key waste-to-energy technology groups

Technology groups	*Short description*	*Waste stream*	*Output*	*Scale and investment costs range*
Co-processing	The use of waste-derived materials to replace traditional fossil fuels in industrial processes, especially in the cement industry. The waste	High-calorific fractions of domestic waste, C&I waste or RDF. The calorific value	Power, heat and ash	From EUR 5 million to EUR 25 million for a 50 kt/year facility, including pre-processing.

Technology groups	*Short description*	*Waste stream*	*Output*	*Scale and investment costs range*
	streams are pre-treated and transformed into RDF to ensure a controlled combustion	of RDF should be approximately 10–15 MJ/kg		From EUR 20 to EUR 45 total cost per tonne of waste handled, including capital cost and O&M costs
Incineration with energy recovery	Seeks to recover energy from the waste stream through the direct combustion of materials. The standard approach for recovering energy is to use combustion heat through a boiler to generate steam that can be further used for heating or producing electricity	Certain fractions of untreated domestic waste, C&I waste, residual waste, or RDF. The lower calorific value should not be below 7 MJ/kg	Heat, dust, gaseous air pollutants, incinerator bottom ash	10 to 500 kt/year. From EUR 135 million to EUR 185 million for a 150 kt/year facility From EUR 260 to EUR 295 total cost per tonne of waste handled (including capital cost and O&M costs)
Anaerobic digestion	Operating in the absence of free oxygen, this process relies on the biological degradation of organic waste by microbes under strictly controlled conditions to produce biogas and in certain conditions a solid-liquid residue called digestate that can be used as organic fertilizer	Organic waste as agricultural residues; source-separated household, market and garden waste; slurries; manure and other putrescible waste	Biomethane, heat and power, nutrient-rich digestate	5 to 150 kt/year. From EUR 12 million to EUR 20 million for a 50–150 kt/year unit. From EUR 22 to EUR 34 total cost per tonne of waste handled (including capital cost and O&M costs)
Gasification and pyrolysis	Both processes refer to degassing waste under oxygen-controlled conditions. They involve the thermal treatment of a waste stream resulting in solid residue (slag or char) and syngas. The main difference between the two processes is the amount of oxygen required during the thermal treatment (pyrolysis involves a complete lack of oxygen, and gasification involves a low level of oxygen). The syngas can be used for heat or producing electricity	Clinical waste, hazardous C&I waste, contaminated soil, treated residual waste	Power, heat, ash/char	10 to 250 kt/year. From EUR 80 million to EUR 120 million for a 250 kt/year facility. From EUR 65 to EUR 85 total cost per tonne of waste handled (including capital cost and O&M costs)
Plasma gasification	Uses a plasma torch to ionize the feedstock and is optimized to produce clean syngas that can be used in gas engines	Clinical waste, hazardous C&I waste, contaminated soil, treated residual waste	Power, heat, slag	10 to 500 kt/year. Limited examples to provide an estimation
Hydrogen economy	The process, carried out in sub-stoichiometric conditions, uses a gasification system which converts organic waste into a uniform and clean burning syngas, as an intermediate step, following a final conversion to hydrogen	High carbon content waste, biomass, animal waste, agricultural waste, municipal sludge, C&I solid waste	Hydrogen, syngas, ash	Limited examples to provide an estimation

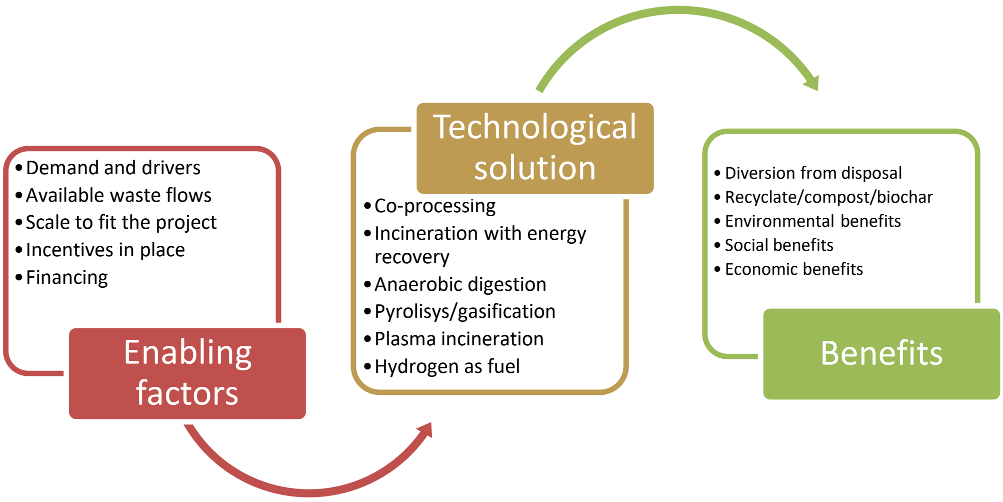
Sources: (1) Deutsche Gesellschaft für Internationale Zusammenarbeit. 2017. *Waste-to-Energy Options in Municipal Solid Waste Management.* Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit. Available at https://www.giz.de/en/downloads/GIZ_WasteToEnergy_Guidelines_2017.pdf; (2) Department of Environmental Affairs, Republic of South Africa; National Greening, Germany Cooperation, and KFW. 2014. *Appropriate Technology for Advanced Waste Treatment – Guideline.* Pretoria, South Africa: Department of Environmental Affairs. Available at https://www.environment.gov.za/sites/default/files/docs/index_advancedwastetreatmentguideline.pdf.

Abbreviations: C&I = commercial and industrial; O&M = operation and maintenance; RDF = refuse-derived fuel; syngas = synthesis gas.

20. The technologies summarized in table 1 are context sensitive, and there is no clear hierarchy of technological desirability. However, the first three technologies are more widespread and involve generally lower capital costs, while the latter three are still considered highly innovative, and experience with these technologies is still limited.

21. The effective management of waste must always consider the existing context and regard waste-to-energy technologies as part of an integrated waste management solution. A wide spectrum of factors would enable or constrain the application of a specific waste management system. Figure 2 presents the enabling factors, technological solutions and desired outcomes or benefits for the waste-to-energy solutions.

Figure 2
Enabling factors for and benefits of waste-to-energy technological solutions



1. Demand and drivers

22. A demand is likely to exist for waste-to-energy projects if, by implementing the project, costly waste disposal or waste treatment is avoided, and the energy and other useful by-products of the project are needed. For example, pyrolysis technology is implemented in coffee farming based on using coffee husks as a feedstock in Viet Nam through a technology transfer from Switzerland to Viet Nam because two of these drivers are in place (see box 1). The coffee cherries need thermal energy for drying, and the fields need expensive fertilizer and irrigation that are both being replaced by the by-product of the technology, which is a sponge-like soil enhancer, the biochar.

Box 1
Pyrolysis–flox, Viet Hien project in Viet Nam

After Brazil, Viet Nam is the second largest coffee producer in the world. With more frequent rainfall during harvest season, coffee drying is becoming a challenge for farmers, as the traditional form of sun drying is not reliable. In this regard, the objective for this project was to introduce pyrolysis technology into Viet Nam's coffee sector to provide reliable heat for drying and biochar, which is a valuable soil enhancer. The project was supported by the REPIC and the United Nations Industrial Development Organization and implemented by Sofies, Viet Hien Ltd., the Swiss Research Institute Oekozentrum and Neumann Kaffee Gruppe.

- Primary waste flow input: coffee pulp
- Energy output: heat and biochar
- Equation: 3 kg of coffee pulp results in 1 kWh energy and 0.5 carbon dioxide stored as biochar.

The project is a showcase of innovative technological action to solve waste challenges while generating multiple benefits. The project relies on local needs and resources to bring state-of-the-art technological solutions to ensure that waste management strategy is efficient and generalizable/replicable.

Source: http://sofiesgroup.com/short-documentary-pyrolysis-technology-new-perspective-efficiently-valorizes-waste-agrofood-industries/.

23. The projects implemented for different waste streams generated in the agro-industry chain in the framework of the Biovalor project in Uruguay respond to the demand for energy and the demand for useful by-products. In Uruguay, there is also an enhanced regulatory framework for the proper treatment of waste and effluents generated in the industry, especially in slaughterhouses and feedlots that drive these types of investments. Another investment supported by the Biovalor project uses ruminal content, which is a type of slaughterhouse waste that is difficult and costly to dispose of. In this case avoiding the costs of disposal is a more powerful driver than an enhanced regulatory framework for waste-to-energy technology (see box 2).

Box 2
Anaerobic digestion – Biovalor project in Uruguay

Biovalor is a project funded by the Global Environment Facility and implemented by the United Nations Industrial Development Organization together with Uruguay's Ministry of Industry, Energy and Mining, Ministry of Housing, Land Management and Environment, and Ministry of Livestock, Agriculture and Fisheries. Its main objective is transforming waste generated from agro-industry into biogas, compost and other agro-based by-products. The project aims at developing a sustainable economically viable model of low greenhouse gas emissions.

Rincon de Albano is a dairy farm supported by the Biovalor project as a pilot for biogas generation.

- Duration of project: four years
- Total investment: USD 200,000 total; USD 100,000 Biovalor support
- Primary waste flow input: manure from 500 cows from a dairy farm (23,725 t/year)
- Energy output: biogas 40,000 kWh/year
- Emission reduction: 276,389 kg carbon dioxide equivalent/year

The project showcases the successful integration of a circular technological solution (i.e. biodigester, water management and treatment) into the existing context, ensuring sustainable energy production while substantially reducing emissions. The energy produced more than meets the farm's demand and the surplus is bought by Uruguay´s Government-owned power company UTE.

Source: http://biovalor.gub.uy/que-es-biovalor/.

24. Demand exists in Morocco for co-processing various industrial waste streams and MSW in the cement industry. The country is the largest cement producer on the African continent, and co-processing waste-derived fuel is an alternative for cheaper fuel compared to the petroleum coke currently used in the industrial process. At the same time, the environmental regulation for waste disposal and leachate treatment is increasing in the country, making it more expensive for municipalities to dispose of waste safely. The demand for co-processing technology emerges from the need for a cheap alternative fuel in the cement industry and as a way to avoid the relatively expensive safe disposal of large amounts of waste.

2. Availability of waste flows

25. The continuous availability of waste flows of a certain quality is a technical requirement for implementing waste-to-energy technologies, regardless of which technology is chosen. The proximity of the sources of waste materials is an important factor, as transporting waste over long distances is not feasible. A general rule regarding the proximity of waste generation is that a distance of up to 100 km is likely to be feasible for transporting feedstock.

26. Part of the waste-to-energy technologies is based on the biodegradation of organic matter and the generation of biogas. These technologies can be relatively small scale with low investment costs and are able to utilize through anaerobic digestion waste flows from agriculture, such as manure, silo, wastewater from food processing and production, green waste and kitchen waste if sources are segregated from MSW, municipal wastewater sludge or a combination of these.

27. As these streams are primarily of agricultural origin, the seasonal variability of the availability of these streams must be considered in planning for anaerobic digesters. For example, the Biovalor project in Uruguay (see box 2) builds around waste streams that are

available year-round (i.e. manure and ruminal content). Synergies and co-digestion of different waste streams may also help in securing feedstock. For example, several projects in South Africa[8] involve co-digesting abattoir waste with sludge from wastewater treatment plants using a technology developed in Austria.

28. For combustion-type processes, the high calorific value of waste is important, as is decreasing the humidity of waste. Certain biomass streams from agricultural waste such as sawdust, wood chips, coconut shells and maize spindles, as well as the dry fraction of municipal waste such as various plastics are relatively high calorific streams and are suitable for combustion. Commercial and industrial waste types or special waste streams such as used tyres of high calorific value are also suitable.

29. Toxicity is a concern for both emissions from combustion and by-products such as ashes, digestate or biochar. Technologies have progressed sufficiently in recent years so that these concerns can be solved by implementing state-of-the-art technologies in any of the categories of technologies mentioned in this paper. Pre-treatment of waste may be needed to ensure the required quality of waste and the protection of environment and public health. Barriers may linger if environmental enforcement is lax or if digestate in legislation is interpreted as hazardous waste, and norms and standards for its use are yet to be developed. Removing inert waste content is important for most technologies to ensure the smooth operation of facilities.

30. Waste-to-energy technologies may be a solution for a specific waste stream that poses a wider biodiversity or pollution threat. For example, by using invasive species and manure, a Christian missionary centre in Samoa developed its own biogas digester using simple materials, and the technology was then implemented in several locations in Tuvalu to manage significant waste streams. Bio-oil was also produced locally through fast pyrolysis from similar waste streams.[9]

3. Scale to fit the project

31. Biogas technology is not very scale sensitive. In terms of scale, for example, the Rincon de Albano project implemented as part of the Biovalor programme in Uruguay uses manure from a relatively small dairy farm of 500 cows as feedstock. The manure input for this plant is about 25,000 tt/year. The technology is available at a family unit scale of 1 to 10 m^3 biogas per day, which is suitable for rural areas that generate energy for self-consumption. It is also available for large and industrial-scale biogas plants with capacity above 5,000 m^3 of biogas production per day (Mittal, Ahlgren and Shukla, 2018).

32. Small-scale biogas technology still faces a number of barriers, including context-specific ones such as lack of water in arid areas or low ambient temperature, but the barriers also often relate to market maturity and high transaction costs. In rural India, for example, despite a long history of supporting policy programmes, market penetration of small-scale biogas is low, mainly due to a lack of proper feedstock and a lack of adapted technologies (Mittal, Ahlgren and Shukla, 2018). Most waste-to-energy technology is focused on a larger scale; thus, smaller economies such as small island developing States (SIDS) or remote rural areas need adapted technologies.

33. In densely populated urban areas, where disposal costs of waste are high due to land scarcity, inadequately managed waste poses serious health problems and is likely to generate more feedstock, and larger scale waste-to-energy technologies are more appropriate in these conditions in centralized systems. Feedstock for this type of technologies may reach 500,000 tonnes per year, which is much larger in capacity than the typical anaerobic digestion or co-processing capacity.

34. When planning such large-scale facilities and investments, the assets are usually meant to operate for at least 20–30 years. Such investments lock in a significant amount of financing and feedstock for a long time. Therefore, the impact of existing and proposed separate collection obligations and recycling targets on the availability of feedstock to sustain

[8] See https://unfccc.int/playground-20/level-2/level-3/tems-m-event-2018presentations-background-information-and-recordings.

[9] See https://unfccc.int/sites/default/files/resource/sprep%20presentation.pdf.

the operation of new incineration plants must be analysed, as well as the planned capacities for incineration in neighbouring cities or countries, but the option of co-processing at different industrial processes such as cement and lime kilns must also be considered (see box 3) (European Commission, 2017a).

Box 3

Co-processing industrial waste – Hongshuihe plant project China

Waste incineration in China presents unique challenges. Its high level of water content and other organic substances means it typically delivers low calorific values, which makes it difficult to produce sufficient energy for cement production. Therefore, when China Resources Cement saw an opportunity to integrate urban and industrial waste into its cement production processes at its 3,200 t/day Hongshuihe plant, it needed to find technology suited to handle the raw waste characteristics. The main objective was to integrate raw urban and industrial waste into cement production using a pyro co-processing facility that involved biomechanical pre-treatment and combustion in a HOTDISC system. China Resources Cement's new co-processing facility already had a positive environmental impact on Binyang by helping to scale back the waste by an estimated equivalent of 0.75 hectares per year and by a reduction in methane emissions by 8.76 million cubic metres a year.

- Beneficiary: China Resources Cement
- Solution: FLSmidth combustion device
- Contractor: SEPEC
- Primary waste flow input: municipal solid waste (40–70 per cent moisture, lower calorific value < 6.3 MJ/kg), refuse-derived fuel; 300 t/day
- Energy output: heat
- Emission reduction: CH_4 3.09 Mt/year.

This project is a successful example of implementing innovative technologies to solve solid waste challenges and contribute to waste reduction.

Source: http://cement.flsmidth.com/h/i/318947526-hotdi sc-a-waste-incineration-solution-like-no-other.

4. Incentives

35. Policy and economic incentives and instruments often support waste-to-energy technologies. The most frequently used incentives are subsidy programmes that offer partial-grant financing or another type of favourable financing instruments such as soft loans or guarantees mostly provided by international financing institutions and national governments. More detail on international and regional support programmes is included in table 3.

36. Incentives may come from regulations in the waste sector that encourage diversion from disposal, and the most commonly practiced regulation is a landfill tax. In case a landfill tax is applied, the gate fee for waste disposal will be higher than the financial cost, which will reflect the negative impacts of generating and disposing waste on the environment and society.

37. A series of other economic incentives for waste to energy comes from regulations in the energy sector that favour renewables, such as feed-in tariffs ensuring the uptake of energy from renewable sources in the grid at better prices or the issuance of tradable green certificates with a guaranteed minimum market value for capacity installed. The European Renewable Energy Directive includes "biomass, landfill gas, sewage treatment plant gas and biogases" as non-fossil sources and sets a legally binding target to achieve 15 per cent of energy from renewable sources, which has been a successful way to encourage waste-to-energy technologies in Europe.

38. The positive experiences of the Biovalor project in Uruguay (see para. 23 above) rely on several incentives. The country's electric micro-generation decree prioritizes buying from micro-producers of less than 150 kW installed capacity in peak hours, during which time the

sellers charge triple the price for the electricity compared to the price they pay for the electricity consumed. The investment promotion act renders tax-exempt investments in renewable energy. Finally, the Uruguay Government sends consistent signals to the market of its long-term commitment to renewable energy and circular economy projects to increase investor confidence in these technologies.

39. Several programmes promote domestic biogas plants, with the main purpose being to use biogas for cooking or other domestic uses. Some countries have been successful. An example of success is Nepal, where more than 330,000 such plants have been installed for households (Scarlat, Dallemand and Fahl, 2018). Among the success factors are sustained donor support and national subsidies for the programme, technical assistance and capacity-building for implementing and operating the technology and an offer of attractive credits for operation.

5. Financing

40. Financial sustainability considerations are inherent to any project. In the case of waste to energy, important aspects to consider when deciding on investment are gate fees that may be charged and are affordable, current disposal costs that will be avoided with the waste and energy and transport requirements. Added to these are the incentives discussed in paragraphs 35 to 39 above and the demand factors.

41. Available financing is a major enabling factor for a project. Financial resources play an important role since most of the credit lines or financial support mechanisms require co-financing. For example, in the Biovalor projects in Uruguay, having co-financing is a condition, and the beneficiaries are putting up 50 to 80 per cent of the financing requirements in the case studies examined.

42. In the case of small-scale investments, financing from international financing institutions may be difficult, as the institutions usually finance large investment projects. This is the case of the SIDS, where project scales are generally small.[10] Financing through community participation in a shareholder scheme can be explored as a solution for financing small-scale decentralized investments.

43. Waste-to-energy projects are not just business cases, and are supported by policy and economic instruments and financing programmes due to the wider benefits and positive impacts they have on society in terms of improved resource and energy efficiency, reduced waste disposal and environmental, social and economic benefits. The benefits are different depending on the technology chosen and will be considered by local decision makers as factors when choosing between technical options.

44. Lowering disposal rates, decreasing the associated pollution and moving up on the waste management hierarchy from disposal to energy recovery is a clear benefit of all the waste-to-energy technologies. If a technology manages to treat a special waste stream that is hazardous or difficult to treat, such as the Biovalor project in Uruguay treating the ruminate of cows, an extra benefit is reducing environmental harm and avoiding costs. Another example was using innovative gasification technologies to treat invasive species in the South Pacific Region.[11]

45. Some waste-to-energy technologies result in valuable by-products. For example, in the case of refuse-derived fuel production during sorting, recyclable materials are lifted from the waste streams and sent to recycling. In the case of anaerobic digestion, the digestate produced may be used as fertilizer if it complies with quality requirements. The selected technology can produce the much-needed biochar in the case of the Viet Hien project, where expensive chemical fertilizers and irrigation were replaced by this sponge-like natural soil enhancer that was a by-product of the technology.

46. Additional benefits of waste-to-energy technologies include the opportunity to generate energy to satisfy the basic energy needs for cooking in communities or homes in

[10] As footnote 9 above.
[11] As footnote 9 above.

rural areas where poverty and access to food are common problems. Waste-to-energy technologies may foster community-based business development in symbiosis to the plant that may be able to buy the energy at favourable prices.

47. Operating waste-to-energy plants requires personnel and a new set of skills and know-how, which is both a constraint and an opportunity. If capacity-building and training programmes are available, human resources may be prepared to attain a new set of skills to operate anaerobic digestion plants or other technologies, depending on the investments.

C. Supply chain redesign and industrial waste reuse and prevention solutions

48. Supply chains connect natural resources with consumers through material and energy flows. Raw materials are extracted, materials are produced, a manufacturing process takes place and finally the products are ready. Therefore, all material efficiency strategies and the ways connections are made in the material flow have an impact on supply chain design. Supply chains are complex and continuously evolving. For example, the building sector has changed tremendously in terms of the design, the energy efficiency norms, the types of materials used, and so forth.

49. Industrial waste reuse is maximized by using durable materials and by recovering products and materials at the end of use. Along with reuse, repair, remanufacture and recycling are maximized this way.

50. Prevention is an all-encompassing concept that could refer to any of the strategies or solutions to achieve circularity in the production and consumption cycles. For the purposes of this paper, the concept of prevention is applied mainly to the resource-to-production phase of the economy and touches lightly on the production-to-consumption part.

51. Rather than technologies, the focus of this section is on the strategies, solutions and business models that are applicable across sectors to achieve the circular economy (see table 2).

Table 2
Strategies and solutions for supply chain redesign and industrial waste reuse and prevention

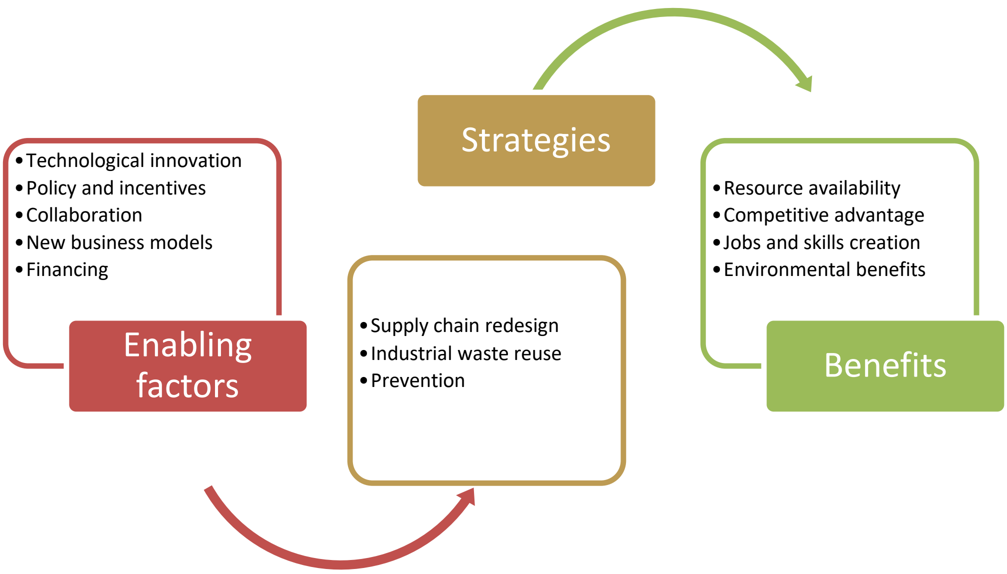
Strategy	*Solution*	*Business model*
Supply chain redesign	• Improve demand forecasting and reduce late cancellation of orders • Avoid losses in retail and supply through digital optimization tools such as real-time shipment tracking, wearable technology, control tower analytics and visualization • Substitute materials and products with more durable ones • Employ shared use	• Co-creation and collaboration • Industrial symbiosis
Industrial waste reuse	• Increase use of secondary materials by improving collection rate, avoiding contamination, reducing losses during waste treatment and avoiding downgrading • Utilize an alternative valorization of unavoidable waste: composting, bio-based materials, animal feed, anaerobic digestion, nutrient recycling and waste to energy • Improve cooperation between industries to swap raw materials for secondary materials from other industries so waste becomes a resource and raw material acquisition and waste management costs are avoided • Design for reuse and dismantling	• Contracts based on key performance indicators rather than on tonnes of waste handled • Industrial symbiosis and synergies • Servicing and maintenance, and lifetime guarantee
Prevention	• Improve design and use higher value durable materials • Design to increase durability • Improve modularity of components for repair or reuse and standardize components • Reduce the total material input required to produce a given product or structure	• Investing in research and development • Servicing and result-based contracts

Strategy	*Solution*	*Business model*
	• Reduce process losses through process optimization and digitalization • Reduce amount, and improve composition and functionality, of packaging • Design to produce 'product and secondary materials', not 'product and waste', if production discards are unavoidable	

52. Current trends of transitioning towards a circular economy are intensifying, stimulated by a shift in mindsets. The way people think about public and private goods and services, produce and consume, and live is changing. For example, the increase in services such as Mobike[12] or Blabla Car,[13] which are businesses built around the concept of sharing bicycles and cars, respectively, indicates travel has changed in the last decade. Changes are happening across all industries and sectors, even if the changes are not immediately visible to the public eye. To describe the shift in their business model, SUEZ[14] stated, "we are no longer managing assets, we provide services".

53. As the economy is being radically reorganized, driven by technical innovation and ambitious policies, new business models and cooperation models are emerging that reinforce each other and enable solutions. The benefits of implementing the solutions of supply chain redesign and industrial waste reuse and prevention include resource efficiency, competitive advantage and jobs and skill creation in emerging market segments (see figure 3).

Figure 3
Enabling factors for and benefits of supply chain redesign and industrial waste reuse and prevention



1. Technological innovation

54. Technological innovations can include process-related innovations that use existing technologies and materials in new combinations, or innovations that are revolutionary and disruptive that stem from using new materials, industrial biotechnology, and digitalization in the supply chain. The circular economy needs more traditional research and development

12 Mobike is a fully station-less bicycle-sharing system headquartered in Beijing, China. It is, by the number of bicycles, the world's largest shared (for hire) bicycle operator. More information available at https://mobike.com/global/.

13 Blabla Car is an online marketplace for carpooling with service available in 21 countries. Its website and mobile applications connect drivers and passengers willing to travel together between cities and share the cost of the journey. More information is available at https://www.blablacar.com/.

14 See https://unfccc.int/playground-20/level-2/level-3/tems-m-event-2018presentations-background-information-and-recordings.

innovations and more disruptive innovations. The TEC has prepared a policy brief, *Technological Innovation for the Paris Agreement*, in recognition of the important role that technological innovation plays in achieving a low-emission, climate-resilient and prosperous future.[15] It outlines the key elements of successful technological innovation and sheds light on the power of technological innovation to accelerate and scale up national climate action.

55. Solutions that result from traditional research and development include cooperation between industries to swap raw materials for secondary materials or to switch traditional fuel for renewables. The efforts of Arcelor Mittal in Brazil[16] to achieve carbon-neutral steel production by cultivating renewable eucalyptus forests and turning the trees into charcoal to use in their processes, thereby replacing traditional fossil fuel, fall into this category.

56. In the same category of solutions are those focusing on avoiding losses in supply chain or production, those improving the use of secondary materials or those utilizing the alternative valorization of unavoidable waste. The efforts of Suez to optimize plastic recovery cycles (see box 4) are included in this type of traditional innovation, as are the efforts of a partnership between IKEA and the World-Wide Fund for Nature[17] to close the loopholes of production. Examples include using digitalization to improve the processes of optimizing supply, production and distribution. In Angola, the Fabrimetal company is transforming metallic waste into reinforced, high-quality steel rods[18] using metal scrap collected from all over the country. The final product is placed on the national market for civil construction and public works or exported.

Box 4

Moving from an asset designer and manager to a solutions provider – Suez

Suez serves 32 million people with waste collection services and treats 4.79 million m³ of wastewater. It creates value by producing alternative water for industrial waste reuse, generating renewable energy from waste and producing secondary raw materials. Suez has invested in optimizing plastic recovery through the RECO® solutions.

Suez has developed a way of giving plastics a second life by using secondary raw materials instead of raw materials. The group has developed the RECO® solutions to speed up the collection and recovery of plastic.

- Innovative and incentivized collection systems
- French consumers are encouraged to sort plastic bottles and deposit them using one of the 100 RECO® kiosks and are rewarded with shopping vouchers worth EUR 1–2). The recovered bottles are sent to processing and recovery centres to be transformed into secondary polymers which are used to produce new products (bottles, food packaging, textiles, etc.)
- More than 125 million bottles have been recovered since 2014
- 7,000 eco-citizens visit the kiosks every day
- Suez has developed the RecyclingBox for small spaces and the RecyclingVan for large events
- Equation: 1 tonne of recycled plastic saves five barrels of petroleum, which is equivalent to 1.6 tonnes of carbon dioxide and up to 90 per cent of energy compared to producing 1 tonne of virgin plastic.

Source: https://www.suez.com/en/News/Press-Releases/SUEZ-gives-plastic-a-new-life-by-encouraging-people-to-collect-with-RECO-solutions.

15 Available at http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf .

16 See https://www.ellenmacarthurfoundation.org/case-studies/new-entry.

17 See https://www.ikea.com/ms/en_JP/about_ikea/our_responsibility/partnerships/ikea_and_wwf_conservation.html.

18 See http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/events_2018_3/94abc15d020f4870b52780643798d9ac/a06d98f7dd1f470dac1f5e89823d47e9.pdf.

57. Disruptive innovation on the other hand radically changes the way people do things or the materials they use. Innovation that substitutes wasteful products or materials with more durable and less wasteful or zero waste products or materials, such as using pipes made from bamboo instead of steel, concrete and plastic pipes, which is an invention from China (see box 5). Replacing cotton with recycled textiles and wood with cellulose fibre are similar types of innovation (Bjorquist et al., 2017). Creating a new product from waste, such as animal fodder from the biodegradable part of MSW, as is done by Agriprotein[19] with the help of black soldier flies, fits in this category as well and will likely radically change the management of biodegradable solid waste.

Box 5

Replacing fossil materials in pipe networks – China

Bamboo winding composite pipelines are made of plant materials, processed and formed by adopted winding technology using resin as adhesive. The pipelines can replace conventional medium- and low-pressure pipelines made of steel, concrete or plastic, bringing significant economic and environmental benefits, saving energy and reducing carbon dioxide emissions in both material sourcing and production process. The energy used during the production process is 75 per cent lower compared to steel pipes and 66 per cent lower compared to plastic pipelines.

If 20 per cent of the steel pipeline market and 10 per cent of the plastic pipeline market were to switch to bamboo pipelines, approximately 63 million tonnes of carbon dioxide equivalent emissions would be avoided.

At present, three production facilities in China produce bamboo winding pipelines on a large scale. The total production capacity is planned to reach 10 million tonnes in 2020.

Sources: (1) http://www.xzbbc.com/en/page/product_detail.aspx?DetailId=403&MenuId=15&ParentId=14&MenuName=Pipelines; (2) http://www.climatesolver.org/innovations/manufacturing/bamboo-winding-pipelines.

58. Eco-design, modular design and design for reuse are solutions that can shake the status quo of the industries. For example, Caterpillar has explored the possibility of reusing end-of-life iron waste components. The company has a Component Rebuild Center and applies the company's reusability guidelines to rehabilitate components to reuse and guarantees the same level of performance as new parts (see box 6). GameStop has established a Refurbishment Operation Center for electronic games and disks to refurbish them for a fee if possible or to dismantle and recycle them.[20] These initiatives are large endeavours and have been successful.

Box 6

Supply chain redesign and refurbishment of industrial components

Caterpillar Inc. has redesigned its supply chain into a responsive and resilient global supply network. The company coordinates the activities of thousands of suppliers around the world, each with its own operating modes and supply chains. By identifying the flows between the supply network nodes, Caterpillar Inc. manages one of the most complex supply networks in the world, which involves coordinating both the flow of information and the physical flow of materials in order to ensure a good collaboration across the network.

WesTrac and Caterpillar Inc. reintroduced the practice of reusability by assessing individual components and machine parts to determine whether they are safe for reuse in a machine or in a component rebuild. The practice was introduced to reduce the disposal of equipment as waste. The process is carried out at the WesTrac Component Rebuild Centre, where customers can request the service. Within the reusability process, guidelines are continuously updated based on experience and results.

Sources: (1) https://www2.deloitte.com/content/dam/Deloitte/za/Documents/strategy/za_Supply_chains_and_value_webs.pdf; (2) https://www.youtube.com/watch?v=9DVFBPMsoh8&t=239s.

2. Policy and incentives

59. Policies and incentives need to underpin supply chain redesign and industrial waste reuse and prevention. In the European Union (EU) and in China strategies related to supply

[19] See https://agriprotein.com/.

[20] See https://www.ellenmacarthurfoundation.org/case-studies/retailer-shifts-to-remanufacturing.

chain redesign and industrial waste reuse and prevention are supported by circular economy policy packages. The challenge with policies and incentives is to support a just transition to a circular economy by safeguarding the transition of the workforce and to eliminate subsidies that may persist in parallel and may impede the transition to a low-carbon economy, such as fossil fuel subsidies or subsidies to resource-intensive industries.

60. Similar policies aimed at increasing resource efficiency, reducing waste and encouraging recycling exist around the world, but different terms are used to describe them. For example, the Swachh Bharat Mission Campaign[21] spearheaded by the Government to clean India by October 2019 is an initiative that supports a circular economy. This campaign aims to achieve the elimination of open defecation in the country and focuses on municipal solid waste management. Many Asian countries have adhered to the 3R initiative to reduce, reuse and recycle. The number of initiatives is likely to increase with the adoption of the Sustainable Development Goals, in particular Goal 12 aiming at sustainable production and consumption.

61. Even in Europe, where several circular economy action plans are in place and adopted, challenges persist due to limited financial resources or a lack of knowledge concerning public sources of funding and how to access these. For example, in Portugal, where an action plan has been developed (see box 7) with wide stakeholder support, 400 small and medium-sized businesses were consulted, 56 per cent did not know of any public funding for energy or resource efficiency or of circular economy projects, and 79 per cent did not think funding other than having their own resources existed for this type of development.

Box 7
Portugal's policy action plan for a circular economy

Portugal, similar to many other countries in the European Union, has prepared an Action Plan for Circular Economy approved and enacted by the Parliament in December 2017. The plan includes national-, sector- and regional-level policy actions and was developed with the engagement of stakeholders at all these levels.
The most immediate actions focus on activities that can be readily undertaken:

- Promoting awareness through disseminating successful business cases through the ECO.NOMIA web portal;
- Organizing roadshows and workshops, and visiting companies working with the principles of a circular economy;
- Allocating financing through the Environmental Funding Program for circular economy projects. The budget for 2018 for these projects is EUR 5 million;
- Organizing market intervention for a fiscal task force for single-use plastic and for decarbonization of the energy system;
- Promoting circular deals such as voluntary agreements between the Government and stakeholders to identify and act on non-financial barriers.

62. In terms of incentives, the implementation of a polluter pays principle will reflect the cost of waste management, and the scarcity of resources will increase the costs of raw materials, thereby encouraging material efficiency and striving for the endless reuse of materials. Economic incentives can be considered to encourage resource efficiency. In addition to subsidies, these may include a resource extraction charge, a product charge for high-intensity primary raw material products and tax cuts for those using secondary raw materials. For example, France's circular economy road map includes policy action to introduce tax breaks for companies in the fashion industry that reuse and recycle unsold products.[22]

[21] See http://www.uniindia.com/swachh-bharat-abhiyan-most-significant-cleanliness-campaign-by-prime-minister/other/news/976687.html.

[22] See https://www.ecotextile.com/2018042523440/fashion-retail-news/france-proposes-law-to-tackle-unsold-clothing-problem.html and https://www.businessoffashion.com/articles/news-bites/what-should-french-fashion-do-with-its-unsold-clothing.

63. An important and large area of work is developing ‘end of waste’ criteria. If it were possible for materials to leave the waste management system and stop being categorized as waste, their utilization would be more likely. The European Commission has developed such criteria for several waste streams, including glass cullet and various ferrous and non-ferrous scrap.[23]

64. Most policies around the world are still embedded in the take-makes-waste linear economy mindset. For example, continuing to tax waste and labour while not taxing resource extraction will impede the transition towards a circular economy. Moving forward requires a screening of virtually all existing policies, such as fiscal, agro-industry, energy and waste management, to make sure that nothing is left to create disincentives and drawbacks.

3. Collaboration

65. Collaboration, awareness-raising and participation are seen in many policy action packages for a circular economy as paramount for success. This is the case in Portugal’s action plan (see box 7), which includes a focus on workshops and road shows, and sharing experiences through a portal, and for example in Scotland’s “Making things last: a strategy towards circular economy”,[24] which provides support to businesses and front-runners, and disseminating good practices occupies a central role.

66. Stakeholders should understand that a circular economy can only exist within the concept of a partnership with delivery partners and not through top-down or bottom-up approaches. Everybody needs to participate. This participation is increasing through on- and offline platforms for dialogue, for incubators for innovation and through encouraging social enterprises and community-based initiatives.

67. Terms such as co-development and co-delivery are often used when describing circular economy initiatives, such as industrial symbiosis or initiatives based on sharing, but also when referring to the behaviour changes of consumers who then trigger demand and change. For example, Suez, one of the largest waste management operators in the world, is involved in co-developing industrial solutions for incorporating new secondary raw materials in the processes of its clients (see box 4).

68. Cooperation is also seen as key for making cities more resource efficient. Cities are the most important contributors to anthropogenic GHGs. Cities also have great potential for cooperating, and cooperation is needed among the various stakeholders, including citizens, local authorities, public utility service providers, commercial entities and industries. For example, one of the main objectives of Paris’s Circular Economy Action Plan is linking businesses and citizens.[25]

69. Value in co-creation and collaboration is based on knowledge exchange that drives the production of goods and services rather than just on the production itself. In fact, many supply chains are evolving into value webs that span and connect whole ecosystems of suppliers and create flexibility, reduce costs and improve service levels. Many of the digital tools created to optimize flows, forecast demand, eliminate losses or track shipments ensure that the rigour in the supply chain is more precisely and easily controlled, thereby allowing the participation of multiple smaller actors (Kelly and Marchese, 2016).

4. New business model

70. Business models are evolving in the context of the circular economy to accommodate technical innovation, respond to ambitious policies and drive change. For example, waste management operators, such as Suez (see box 4), who have traditionally been closing contracts and have been paid based on tonnes of waste handled are increasingly being contracted to reach key performance indicators related to resource efficiency and waste prevention. The interest of these companies is no longer to manage more and more waste but to co-create solutions to reduce it, which could eventually lead to cleaner production business models that are energy service company type models but implemented to increase material efficiency and process efficiency rather than energy efficiency.

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23 See http://ec.europa.eu/environment/waste/framework/end_of_waste.htm.
24 Available at https://circulareconomy.europa.eu/platform/sites/default/files/making_things_last.pdf.
25 See https://api-site-cdn.paris.fr/images/97397.

71. Products increasingly become services, and people are more interested in buying services than being pinned down and linked to assets for a long period of time. Owning a multitude of products is increasingly incompatible with the flexible ways businesses operate and with the ways companies create value. For example, the availability of cloud-based data storage has changed how information is stored, and storage has become a service rather than hardware.

72. Owning is replaced by sharing, which is a measure that increases the productivity of materials and products, reduces costs and increases profits for asset owners. Policy has been supporting such initiatives as car sharing, and industrial parks or commercial areas with shared facilities and urban development with shared facilities are also becoming increasingly popular.

73. Industrial symbiosis is both a solution and a business model that occurs when one company is using the waste or by-product of another industrial process as a raw material in its own production process. The concept is not as new in certain countries, such as the United Kingdom of Great Britain and Northern Ireland[26] and Sweden,[27] where the first industrial parks aiming at industrial symbiosis were established in the mid-1900s.

5. Financing

74. Business models, even if risky, will be set up so they generate profit and value in the long term. Companies often need financing to risk more. Innovation needs more "patient" financing, that is, smaller scale finance with an appetite for higher risks and often an opportunity for higher gains. Governments are increasingly interested in financing innovative projects through subsidies. The EU has several programmes set up for financing these projects, including Horizon 2020, which is more research oriented; LIFE, which is more industry oriented; and Urban Innovative Actions, which is oriented towards cities.[28] The India Innovation Fund is a technology innovation fund[29] from 2011 that provides up to 80 per cent of the financing required for start-ups.

75. Circularity creates value to those who invest in it. Moving from providing a product to providing a service or a service–product hybrid means investments must be made, but it has been a strategy to curb the impact of economic recession on companies. Customers are provided with the opportunity to lease or rent equipment that they can no longer afford to buy, in addition to continued maintenance service. Over the long term, rental/lease services can turn into a win–win strategy for the companies and the clients. Typical products that may be used this way include industrial cleaning or logistics equipment.

6. Benefits

76. Moving to a circular economy is imperative because there is mounting pressure on resources, and waste generation is a major source of pollution. Both of these factors are improving in the transition towards circularity, and dependence on imports is also reduced. These measures also have very significant energy savings and thus mitigation impacts. For example, the cumulative increase in recycled plastics production accounts for a cumulative decrease of 4 per cent in primary chemicals production, which enables energy savings equivalent to 12 per cent of the global industrial total final consumption (International Energy Agency, 2018).

77. For those who take the risk and are on the forefront of innovation in implementing the strategies and solutions discussed in supply chain redesign and industrial waste reuse and prevention, the investments are likely to create a competitive advantage in the long term. Caterpillar Inc., for example, has transformed its supply chain into a much more resilient value web, as shown by the way the company was able to modify its supply chain in only 45 days after the tsunami and earthquake in 2011 in Japan.

78. A just transition to the circular economy involves knowledge-sharing and training. Some of the changes are related to automation, but much of the industrial waste reuse, for

[26] See http://www.wrap.org.uk/content/industrial-symbiosis-uk.
[27] See http://www.industriellekologi.se/symbiosis/.
[28] See http://www.uia-initiative.eu/en/uia-cities.
[29] See http://www.indiainnovationfund.in/aboutus/index.

example, will require a trained workforce. The green economy can bring jobs but it requires greater integration of greening policies with education and training of the workforce.

79. As long as businesses see the circular economy as an opportunity and not as a threat, and governments help in retraining the workforce rather than protecting jobs in a high resource and energy intensity sector, the potential gains are real. After analysing the job-creation impact of the circular economy, the Waste and Resources Action Programme in the United Kingdom concluded that under the current development scenario, 54,000 jobs can be created in the sector until 2030, which would lead to a 0.15 per cent reduction in the unemployment rate in the country. If a more ambitious, transformative scenario were implemented for resource efficiency, the results would double the number of jobs created.[30]

D. Sector-wide status quo

80. As can be seen from the discussion above, (1) waste to energy and (2) supply chain redesign and industrial waste reuse and prevention solutions are very different. While waste to energy was discussed in terms of technologies and the potential uptake of these technologies in different local contexts, supply chain redesign and industrial waste reuse and prevention solutions is a broader topic discussed on the basis of existing solutions that can be technologies, system changes and tools in production and consumption processes. The extent to which these latter solutions have penetrated the market is more difficult to judge; their applicability spans across all production and consumption patterns of the global economy.

81. As far as waste to energy is concerned, the market penetration of co-processing, incineration with energy recovery, biomass combustion and anaerobic digestion is significant, while the implementation of the rest of the groups of technologies discussed (see table 1) is in various stages of development or testing or is only implemented in limited cases. According to the European Commission study on research and innovation in the circular economy, in 2014 approximately 1.5 per cent (i.e. around 676 PJ/year) of the total final energy consumption in the EU was met by recovering energy from waste through incineration, co-incineration in cement kilns and anaerobic digestion (European Commission, 2017).

82. Of these technologies biogas technology, given its relative flexibility, is the most globally applied technology. Global biogas production increased from 280 million GJ in 2000 to 1280 million GJ in 2014, with a global volume of 59 billion m^3 biogas (Scarlat, Dallemand and Fahl, 2018). Incineration market trends in Europe, Asia and North America show a significant increase, especially in Asia (from USD 616 million in 2006 to USD 1,749 million in 2011) (World Energy Council, 2016).

83. Supply chain redesign and industrial waste reuse and prevention are being implemented in various industrial sectors around the world. There is currently no standardized metric to measure and trace these initiatives, thus a sector-wide status is difficult to establish for the uptake of these solutions. Taking material extraction trends as a proxy for the way resources and materials are used and reused, material flow accounting helps establish a baseline.

84. Existing evidence suggests that current overall trends still show increasing material extraction and consumption, but a decoupling of growth from resource extraction and waste generation is not yet being achieved. If current extraction trends continue, material resources – biomass, fossil fuels and non-metallic minerals – may more than double from 2015 to 2050, being close to 90 billion tonnes (International Resource Panel, 2017).

E. Support schemes

85. The results in (1) waste to energy and (2) supply chain redesign and industrial waste reuse and prevention sectors could not have been reached without the continued support of regional and global initiatives of international organizations, donor agencies and bilateral funds. Programmes rarely finance subtopics of a circular economy such as those in this paper.

[30] See http://www.wrap.org.uk/sites/files/wrap/Employment%20and%20the%20circular%20economy%20summary.pdf.

However, several climate finance programmes, waste and chemicals management programmes, renewable energy and energy efficiency programmes or more general circular economy programmes finance elements that all contribute to a transition to a circular economy. Table 3 lists a selection of such initiatives.

Table 3
Selection of measures and programmes supporting relevant circular economy activities

Supporting organization	*Title of the programme and link to website*	*Objectives or key topic and activity financed*	*Range of financing*	*Location*
African Development Bank Group and the Government of Denmark	Sustainable Energy Fund for Africa https://www.afdb.org/en/	Small- and medium-scale renewable energy generation and energy efficiency projects	USD 42 million (2016)	Africa
C40 Cities	https://www.c40.org/	Climate action and zero carbon cities		International
Climate Technology Centre and Network	https://www.ctc-n.org/	Accelerate transfer of environmentally sound technologies for low carbon and climate resilient development		International
Ellen MacArthur Foundation	https://www.ellenmacarthurfoundation.org/	Circular economy, applied research		International
European Regional Development Fund	http://ec.europa.eu/regional_policy/en/funding/erdf/	Urban circular economy, implementation of projects at city level	EUR 10.1 billion (2014–2020)	Europe
European Union and United Nations agencies	Sustainable Energy for All https://www.seforall.org/	Energy access, renewable energy, energy efficiency		International
Global Environment Facility	The Global Environment Facility Trust Fund https://www.thegef.org/	Chemicals and waste	USD 554 million (2014–2018)	International
Green Climate Fund	https://www.greenclimate.fund/home	Mitigation impact, adaptation impact and cross-cutting	USD 10 billion, different size projects and programmes	International
Horizon 2020	http://ec.europa.eu/programmes/horizon2020/	Circular economy, research and innovation		Europe
ICLEI – Local Governments for Sustainability	http://www.iclei.org/	Systematic urban change, global climate action and sustainable urban development		International
International Chamber of Commerce	International Chamber of Commerce https://iccwbo.org/	Circular economy, supply chain management and resource efficiency		International
LIFE program	http://ec.europa.eu/environment/life/	Innovation in environmental technologies	EUR 400 million (2018)	Europe
NAMA Facility	Inspiring Ambitious Action on Climate Change http://www.nama-facility.org/	Low-carbon developments in the forestry, transport, agriculture, waste, renewable energy and energy efficiency sectors	EUR 5–20 million/project	International

Supporting organization	*Title of the programme and link to website*	*Objectives or key topic and activity financed*	*Range of financing*	*Location*
SNV (Netherlands)	http://www.snv.org/	Agriculture, energy, water, sanitation and hygiene	EUR 100 million (2017)	International
United Nations Industrial Development Organization	Inclusive and sustainable industrial development https://isid.unido.org/index.html	Innovation in industrial development		Peru, Senegal, Ethiopia
World Business Council for Sustainable Development	World Business Council for Sustainable Development https://www.wbcsd.org/	Circular economy, climate and energy		International

86. Box 8 highlights initiatives undertaken by the private sector and cities.

Box 8
Examples of initiatives/partnerships supporting circular economy activities

World Business Council for Sustainable Development: Factor 10, Circular Economy project. This brings companies together to reinvent how business finds, uses and disposes of the materials that make up global trade. It is a platform that helps to identify and remove the barriers that exist and create scalable solutions that businesses all around the world can use.
ICLEI – Local Governments for Sustainability: Green Circular Cities Coalition. This provides a platform where cities, experts, businesses and other relevant stakeholders connect to foster urban circular economy transition through knowledge and experience exchange, mutual learning and technical support.

Sources: (1) https://www.wbcsd.org/Programs/Energy-Circular-Economy/Factor-10; (2) http://eastasia.iclei.org/activities/programs-projects/green-circular-cities-coalition.html.

III. Where do we want to go?

A. Lessons learned

87. Lessons learned in terms of enablers and barriers are summarized in tables 4 and 5. The opposite of an enabling factor is often a barrier and vice versa; nevertheless, it is important to acknowledge lessons learned in both respects to be able to construct a viable action plan. The enabling factors listed in both tables are embedded in good practice examples from the status quo and reflect the different support schemes, policy initiatives, innovations in technology and incentives that exist in the global community to advance in waste to energy and supply chain redesign and industrial waste reuse and prevention. Barriers indicate areas for improvement and actions that may unlock the mitigation potential in the above-mentioned fields.

88. One important factor for success that has not been discussed in detail through the examples but is the backbone of all the projects is related to human resources and the available capacities, namely: (1) the capacity to attract and manage initiatives in the sector as a client on the part of authorities, (2) the capacity of the private sector to innovate and invest in innovation, its appetite to assume risks related to innovations and the capacity to implement and operate projects in the sector; (3) the capacity of the financing sector to understand the projects and offer suitable project financing; and (4) the capacity of a larger stakeholder group participating in the project either as buyer of the output or product or as user of the service to follow the trends or shape the resources and waste management from the demand side. Capacity is a challenge for scaling up in middle income countries, but even more so in the least developed countries and SIDS.

89. The enablers and barriers in waste to energy are more project and technology related, and point to the concrete incentives and policy support needed (see table 4).

Table 4
Enablers and barriers for waste-to-energy technologies

Issues	*Enablers and success factors*	*Barriers and challenges*
Demand and drivers for change	• Existence of demand for energy or other outputs of the technology • Strict and enforced environmental regulation associated with high costs of disposal that may be avoided with waste-to-energy technology • Scarcity of land for disposal	• Lack of demand for energy from waste or technical or market barriers to feed electricity to the grid • Lack of a gate fee or low gate fee at disposal sites
Availability of waste flows	• Availability of sufficient quantity, quality and composition of waste flows as feedstock • Opportunity to combine waste streams from different sources	• High seasonal fluctuation in quantity and composition of waste flows • Mixed waste flows containing a lot of sand, debris or hazardous waste that may pose difficulties in operating facilities
Scale and scale-sensitivity	• Availability of technology at the required scale, which is the case for anaerobic digestion technology and co-processing	• The need for economies of scale to make the technology financially viable, as is the case with incineration with energy recovery, gasification and plasma technologies and hydrogen production technologies
Incentives	• Feed-in tariff and/or green certificates for renewable energy • Incentives for using fertilizer obtained from biodegradable waste • Subsidies for capital investment or operational cost • Tax cuts or exemptions	• Insufficient incentives • Legal barriers to feed in or sell the generated energy • Changing incentives that make planning investments difficult
Financing	• Existence of uptake market • Affordable gate fees at the facility for the feedstock • Availability of financing at the right scale	• Lack of resources and financing sources

90. The factors in supply chain redesign and industrial waste reuse and prevention are framework and systems related, and point to the need for a paradigm shift in technology, policy, incentives, financing and cooperation in order to deliver solutions (see table 5).

Table 5
Enablers and barriers for supply chain redesign and industrial waste reuse and prevention

Issues	*Enablers/success factors*	*Barriers/challenges*
Technical innovation	• Digitalization • Bioengineering • Big data, real-time tracking, optimization tools • Eco-design • Nature-based solutions	• A lack of investment in technical innovation and research and development • Recycling is still down-cycling • Toxicity of waste prohibits reuse and recycling

Issues	*Enablers/success factors*	*Barriers/challenges*
	• Traditional research and development	
Policy and incentives	• Ambitious targets for recycling • Circular economy package • Changes to end-of-waste definitions • Extended producer responsibility • Charges on mineral extraction and wasteful products while lifting taxing on labour and waste	• Retaining policies and incentives that favour traditional resource- and energy-intensive industries • Subsidies to fossil fuel use • A lack of mainstreaming policies to the concept of the circular economy in other policy areas such as renewable energy and fiscal policy • Leakage of waste streams from developed to developing countries
Collaboration	• Co-creation of technical innovation and policies • Co-delivery in delivering solutions • Incubators and hubs for innovation	• Loss of jobs • Lack of skills and capacities to create, implement and manage projects
Business models	• Offering products as a service • Owning replaced by sharing • Industrial symbiosis • Performance indicator based contracts for waste operators	• Lack of sufficiently ambitious circular economy policies • Legal barriers that may hinder new initiatives, such as protection of existing industries and trades through permitting systems, certification systems and the like • Definition of waste-derived products as waste hinders their use
Financing	• Availability of patient finance suitable for innovation – mid-size soft loans or guarantees	• Only large investment amounts available that are not suitable for innovation • Risk aversion in financing • Lack of understanding by the financiers of the new technologies and their financial structure • Difficulty in financing innovation and competitive advantage from public funds

B. Mitigation potential

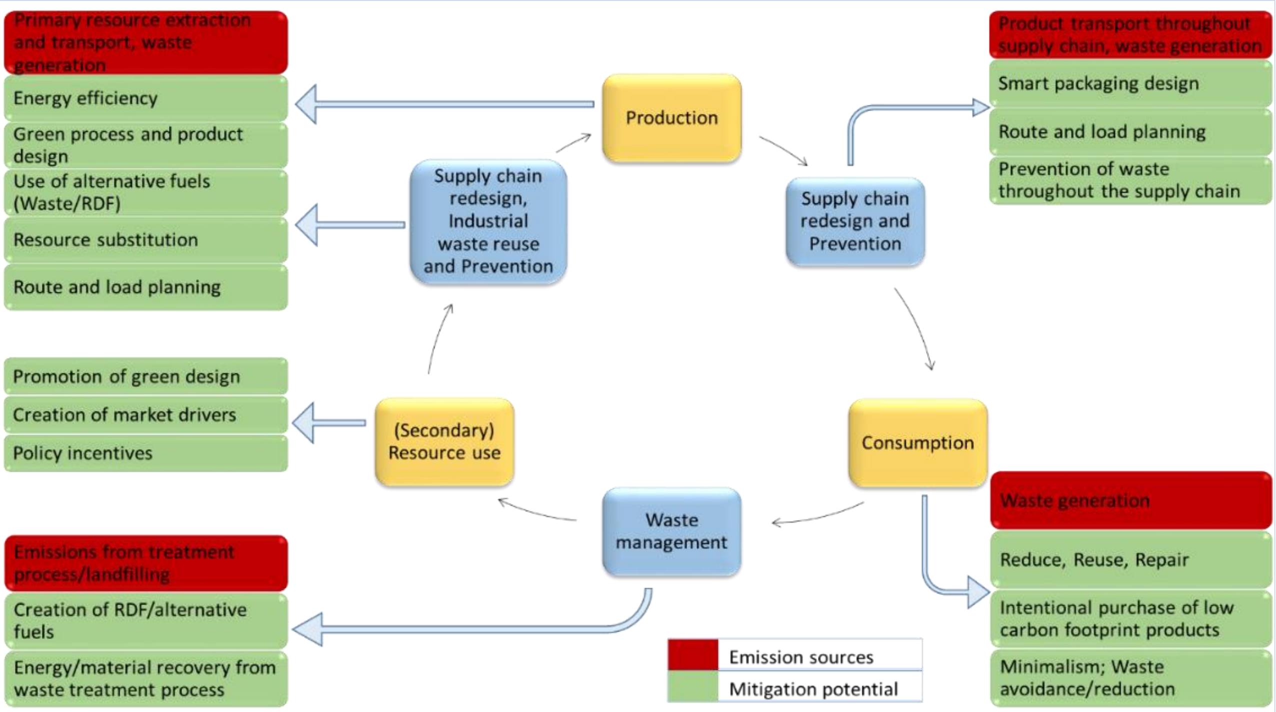
91. The Intergovernmental Panel on Climate Change (IPCC) *2006 IPCC Guidelines for National Greenhouse Gas Inventories* contains information on GHG emissions based on sectors where these gases originate. The waste-to-energy initiatives and supply chain redesign and industrial waste reuse and prevention are solutions that change several emitting sectors, including extraction of materials, production processes, consumption patterns and waste management activities. Major sources of emissions in these areas include fossil fuel combustion for energy, emissions generated in extraction, production and waste management processes, and emissions related to transport and logistics in supply chains and reverse supply chains.

92. Likewise, the potential for mitigation may arise from many different interventions, including less energy-intensive processes, use of secondary materials with less embedded carbon, reduced need for transport through optimization of supply, avoiding biodegradation in disposal sites by diverting waste from landfilling to waste-to-energy treatment and

replacing fossil fuel with waste or waste-derived fuels as an alternative source of energy. Figure 4 is a simplified interpretation of potential sources of emissions and of mitigation.

Figure 4

Sources of emissions and mitigation potential in the focus of waste-to-energy initiatives and supply chain redesign, industrial waste reuse and prevention solutions



93. In its Fifth Assessment Report, the IPCC estimated total anthropogenic GHG emissions at 49 Gt carbon dioxide equivalent (CO_2 eq) in 2010, with 35 per cent coming from the energy supply sector, 24 per cent from agriculture, forestry and other land use, 21 per cent from industry, 14 per cent from transport and 6.4 per cent from buildings. The share of waste and wastewater sector emissions is around 3 per cent, and about half of this is attributed to methane generation in waste disposal sites. In this accounting system, all energy supplied to industry and buildings, for example, is attributed to the energy supply sector, so interventions to mitigate the sectors that target energy consumption will also reduce the emissions accounted for in the energy supply sector (IPCC, 2014).

94. The United Nations Environment Programme and the International Solid Waste Association (2015) suggest that if mitigation options for waste management, such as fuel switch due to waste-to-energy treatment, are explored upstream and downstream, the potential emission reductions could reach 10–15 per cent of current global emissions, or 4.9 to 7.35 Gt CO_2 eq. Waste to energy is a significant contributor for reaching that potential, as it both diverts waste from disposal and produces a fuel switch, thereby achieving mitigation in both the waste and the energy supply sectors.

95. For example, approximately 1.5 per cent (i.e. around 676 PJ/year) of the total final energy consumption of the EU in 2014 was met by recovering energy from waste through incineration, co-incineration in cement kilns and anaerobic digestion. As more waste is directed to recycling, improving the energy efficiency of waste-to-energy processes and promoting those processes that combine material and energy recovery can contribute to decarbonizing key sectors such as heating and cooling or transport. For instance, diverting 1 t biodegradable waste from a landfill towards anaerobic digestion to produce biogas and fertilizers can prevent up to 2 t CO_2 eq emissions (European Commission, 2017).

96. When looking at the potential for mitigation through complex circular economy strategies, including supply chain redesign and industrial waste reuse and prevention, the evidence of what can be achieved through these strategies is still limited. Material extraction is still increasing globally. The International Resource Panel (2017) estimates that a 26 per

cent reduction in material extraction and a further 15–20 per cent reduction in GHG emissions could be achieved with ambitious policies until 2050.

97. Households generate around 2 billion t MSW each year. Adding industrial, construction and demolition waste to this, solid waste generated annually totals 7–10 billion t (United Nations Environment Programme and International Solid Waste Association, 2015). Per capita generation rates of MSW average between 50 and 400 kg/year in low- and middle-income countries (European Commission, 2017), whereas the rate generated in high-income countries is 300–790 kg/year (Eurostat, 2017).

98. Some high-income countries have achieved a relative decoupling of waste generation from gross domestic product, and the trend continues. However, the trend is the opposite in low- and middle-income countries. Even though these countries have relatively low waste generation rates, they are likely to generate more waste both per capita and in absolute terms due to increasing consumption and population. From an estimated 7.6 billion in 2017, world population is expected to surpass 8.5 billion by 2030 and 9.7 billion by 2050 (United Nations Department of Economic and Social Affairs, Population Division, 2017).

99. An examination of emission reduction potential in the circular economy and of interventions in the production and consumption of products, rather than just waste management, revealed emission reduction can reach between 30 and 50 per cent of the emissions attributed to the industry sector. Circular economy measures have the potential to reduce the emissions related to the production of goods consumed in the EU by 33 per cent (Deloitte Sustainability, 2016). A recent report by EIT Climate-KIC[31] estimates that the circular economy can make deep cuts to emissions from heavy industry, including steel, aluminium, plastics and cement production, namely 3.6 Gt CO_2 eq or 50 per cent of the emissions from industry can be mitigated through this type of intervention. Table 6 presents examples of the mitigation potential of some industries through implementing different circular economy solutions and technologies.

Table 6
Examples of mitigation potential through implementing different solutions and technologies

Industry or sector	*Reduction opportunity*	*Practical measures to be implemented*	*Climate change mitigation potential per year*
Steel	Reducing primary steel by increasing reuse and recycling and by ensuring higher-quality production	• Promoting high-quality secondary production • Avoiding copper contamination • Increasing collection of post-consumer scraps	41 Mt CO_2 eq Estimated for Europe
Plastic	Increasing the amount of recycled plastic and promoting secondary plastic production	• Implementing a product design for recycling • Increasing regional integration of markets • Developing technical solutions for better sorting, automation and chemical recycling	117 Mt CO_2 eq Estimated for Europe
Aluminium	Improving the recycling process for aluminium by reducing losses, processing scrap and avoiding downgrading	• Reducing collection losses • Increasing alloy separation in scrap recycling, thus increasing the quality of secondary aluminium • Reducing scrap from production	26 Mt CO_2 eq Estimated for Europe
Construction (building	While relatively low, recycling for cement	• Further development of smart crushers and increased use of	80 Mt CO_2 eq Estimated for Europe

[31] Available at http://www.climate-kic.org/areas-of-focus/sustainable-production-systems/our-insights/.

Industry or sector	*Reduction opportunity*	*Practical measures to be implemented*	*Climate change mitigation potential per year*
materials and cement)	can be increased through the reuse of structural segments. A more efficient use of other building materials can lead to a 30 per cent decrease in the amount of materials used	recovered concrete in construction • Regrinding and reuse of building structural segments • Material savings though the reduction of construction waste • Developing of local and regional markets for the reuse of building components • Space-sharing as a strategy to reduce total floor space	
Passenger cars	Increasing efficiency of the sector by promoting shared car services	• Sharing car services can increase the lifetime/exploitation ratio through the shared-car model • Redesigning the car to decrease the input materials required while maintaining the functionality	19 Mt CO_2 eq Estimated for Europe
Nutrient recycling for animal feedstock	Reusing organic waste to replace fish and soy meal	• Avoiding emissions from transport and landfilling • Enhancing sink due to marine life protection and improved land use	By replacing fishmeal and taking 8.7 per cent of the global market, there is a potential to reduce 23 Mt CO_2 eq Estimated globally
Piping	Rely on alternative or renewable materials to improve the quality of existing pipelines and replace plastic and steal with bamboo	• Avoiding energy consumption associated with steel and plastic pipe production • Avoiding CO2 by material sourcing	By considering a potential share of 20 per cent from steel and 10 per cent from plastic pipes to move to bamboo winding, 63 Mt CO_2 eq can be avoided Estimated globally
Textile	Creating new ways to produce cellulose fibres, recycled textile and wood to replace cotton	• Avoiding CO2 by material sourcing • Avoiding pesticide consumption • Avoiding disposal of cotton and viscose textile	By considering 25 per cent recycling of cotton and viscose and 25 per cent substitution with wood pulp, 14 Mt CO_2 eq can be reduced Estimated globally

Source: http://www.climate-kic.org/areas-of-focus/sustainable-production-systems/our-insights/ and World Wide Fund for Nature presentation at Bonn technical expert meeting 2018.

100. Supply chain redesign and industrial waste reuse and prevention strategies are impactful and may lead to quick wins on material (especially metal and plastics) intensive industries, like automotive and electronic and electrical appliances. Waste-to-energy technologies are equally important for offering accessible end-of-pipe solutions with significant mitigation potential for waste that cannot be reduced, reused or recycled.

C. Co-benefits

101. Co-benefits refer to the sustainable development benefits of the proposed strategies, other than strictly from the mitigation potential, for society in general. The benefits of (1)

waste to energy and (2) supply chain redesign and industrial waste reuse and prevention are many and fall into environmental, economic or social benefits that provide additional motivation for the projects and developments to be pursued, in addition to the mitigation potential and the pressure on the economy from the depletion of natural resources.

102. Environmental benefits include diversion from disposal and thus less pressure on the environment in terms of soil, water, groundwater table and air pollution usually associated with disposal. Circular economy also helps to extend the lifetime of existing disposal sites, thereby avoiding pollution of new sites. By reducing extraction, pollution is avoided, biodiversity is maintained and natural resources are conserved. Interventions in the supply chain hold a lot of potential for companies that normally look at environmental impacts on their own premises, but 90 per cent of the environmental impact occurs in the supply chain when looking at environmental analysis from a life cycle point of view (McKinsey Center for Business and Environment and Ellen McArthur Foundation, 2015).

103. When looking at the economic and social benefits of waste to energy options, the gains are clear. Businesses and communities can rely on a new, renewable source of energy to increase fuel security and create opportunities for new business development. Small-scale biogas solutions may be adequate for supplying the energy needed for cooking, reducing fuel poverty and improving quality of life of people living in remote areas or in poverty. By relying on waste to energy, other life-sustaining resources and biodiversity are spared.

104. Circular economy interventions boost resource productivity and lead to a reduction of costs, thereby increasing the competitiveness of those who implement these solutions. For example, the report by the McKinsey Center for Business and Environment and Ellen McArthur Foundation on the economic impact of circular economy measures on Europe shows that a 3 per cent growth in resource productivity linked to circular economy technical innovations would generate a primary resource benefit of EUR 0.6 trillion per year in Europe's economy. Other indirect benefits such as job-creation, reduced costs with waste management and externalities would yield a total annual benefit of EUR 1.8 trillion.

105. Resource extraction activities have been so polluting that they are linked to public health issues. For example, using dirty fuels for cooking leads to premature deaths. Working on waste to energy and on supply chain redesign and industrial waste reuse and prevention will lower the use of energy and resources or will provide an alternative source of energy, thereby reducing public health risks.

106. Another set of risks linked to resource scarcity are conflict, security and migration. As supply shortages of critical materials arise, communities will compete for the materials. Depleting oil reserves, for example, have already become an important factor in international conflicts. Food, land, water and biotic reserves are increasingly scarce, are essential for sustaining human life, and will be positively impacted by strategies for decoupling the use of resources from economic growth.

107. While the transition to a circular economy reduces public health risks and increases resource and energy security, jobs will be lost in traditional material extraction, fossil energy and to some extent manufacturing. It is important to ensure a just transition to the circular economy that will require new skills and expertise. Capacity-building and investment into human resources will be key for a successful transition.

IV. How do we get there?

108. The studied examples and trends show the way for accelerating the implementation of best practices. Choosing high-mitigation actions and accompanying these with capacity-building will ensure maximum mitigation potential and sustainable results. Specific measures to take in the short to medium term are explained in chapter IV.A and IV.B, while an action plan for the short term is included in chapter IV.C.

109. **Targeting and rewarding high-mitigation impact.** To achieve high-mitigation impact, solutions should be chosen during the analysis of various technology or policy options that achieve the highest mitigation impact. The mitigation impact is best understood

by taking into account upstream and downstream impacts of a project, not only direct emissions.

110. **Accompany technology transfer with capacity-building and adapting it to a local context.** Since most of these technologies are homegrown and most are located in the industrialized world, technology transfer needs to be done with care. Many technologies will require altering to fit the local circumstances in terms of waste streams, climate, transport of feedstock and outputs but also need capacity-building of staff and clients to manage the new technology.

A. Waste to energy

111. **Increase security of feedstock through synergies and cleaner waste streams.** One of the keys for technical success in the waste-to-energy sector is securing a continuous flow of feedstock of sufficient quality. It makes sense to combine wastewater sludge, certain streams of municipal waste, agricultural waste and waste from the food industry to achieve the necessary feedstock. Reducing contamination and debris in the waste streams and ensuring a good collection system will ensure a better-quality feedstock and a smoother operation for most waste-to-energy technologies.

112. **Improve knowledge on waste quantities and characterization.** To develop business plans or feasibility studies for waste-to-energy that are credible to both public and private investors, good data on feedstock are needed. Waste data quality is usually poor in developing countries and should be improved. Moreover, data on waste generation across sectors should be collected and studied to make informed conclusions on possible technologies to implement.

113. **Identify and secure demand for energy and by-products from the technology.** Mapping demand for energy for businesses or communities and for other by-products such as soil enhancers and recyclates will enable informed business decisions about waste-to-energy technologies and the choice of the most suitable technology. While economies of scale are related to availability of feedstock, bankability is related to revenue streams that come from off-take agreements and uptake markets that can be secured.

114. **Scale down before rolling out.** There are opportunities for rolling out positive experiences, which shows that risks are only perceived and not real. Before scaling up, however, many of these technologies need to be scaled down to fit the small farmers, small generators of waste or small communities that need these solutions. Rolling out is best done through the involvement of governments that can align the conditions of the different partners participating in financing and implementing the projects.

115. **Implement waste-to-energy technologies through inclusive business models.** Waste to energy solutions need to include waste pickers and their associations to protect the livelihood of those who are most vulnerable. Inclusive business models shift the institutional scene from a purely municipal concern to cooperation between waste picker organizations, municipalities and private operators of biogas facilities.

116. **Waste-to-energy technologies can become attractive if waste disposal and environmental pollution have a price.** Policies need to ensure that waste management and disposal is paid by the polluter at a resource recovery fee or at a higher fee that includes a tax for pollution, such as a landfill tax. In this way, avoiding costs with landfilling will be a significant incentive to invest in other treatment technologies, including waste to energy.

117. **Introduce a mix of policy instruments to support waste-to-energy technologies.** Waste-to-energy technologies have been successful when there has been a concerted effort and a mix of economic and policy instruments have supported such initiatives, including, for example, feed-in tariffs, green certificates for renewable energy, subsidies for using fertilizers from biodegradable waste streams and other subsidies or taxes.

118. **Align financing with needs.** For some technologies, small-scale financing or output-based financing should be made available to support operation costs as well as capital expenses until cost recovery can be achieved. Cost recovery may be achieved in time as uptake markets may need to be developed and policies may need to be aligned before the technology is fully affordable and bankable in commercial terms.

119. **Public private partnership for financing.** Developing public–private partnerships legislation and opportunities for private technology providers to invest and enter into contracts with local or national authorities is a good option for developing waste-to-energy technologies (see box 9). This way the know-how will be secured by the private sector but the burden of financing and the benefits of investing are shared between the public and the private partner.

Box 9

Waste-to-energy projects under the public–private partnership model: Wenzhou City, China, Case Study

The city of Wenzhou, in Zhejiang Province, China, generates about 400,000 t of household waste annually. In the early 2000s, the city operated two municipal landfills, both of which were nearing capacity.

In 2002, the city entered into a contract with a local company, Wei Ming Environmental Protection Engineering, to build and operate a public–private partnership (PPP) waste-to-energy incinerator plant. The private partner would design, finance, build, operate and maintain the incinerator plant, which had an estimated construction cost of CNY 90 million (approximately EUR 12 million).

The contract term was two years to complete construction, followed by 25 years of operation and maintenance. At the end of the contract, the incinerator plant is turned over to the city government at no cost.

The incinerator plant has a design capacity of 320 t of solid waste per day and an electricity generation capacity of up to 25 million kWh annually.

The plant began operation in 2003. During the first phase, the plant treated 160 t per day. Thus, the plant could generate 9 million kWh per year, of which 7 million kWh would be available for sale.

The plant also receives a waste disposal fee of CNY 73.8 per tonne (approximately EUR 10) from the city government.

To encourage PPP investments, China has also exempted waste-to-energy incineration facilities from corporate income tax for the first five years of operation and made them eligible for an immediate refund of value-added taxes.

Electricity network operators are also required to purchase electricity generated by qualified energy producers using renewable energy sources, when available.

Source: United Nations Economic Commission for Europe. 2012. *Case Studies in Green Technology PPP Projects: Waste to Energy*. Available at https://www.unece.org/fileadmin/DAM/SPECA/documents/kdb/2012/Seminar_Kyrgyzstan/Smith1.pdf.

120. Box 10 presents another example of public–private partnership.

Box 10

Waste-to-energy projects under the public–private partnership model: Vancouver cogeneration case study

The city of Vancouver owns and operates one of the largest landfill sites in Canada. The site receives approximately 400,000 t of solid waste annually. It produces landfill gases as a by-product of waste decomposition, including methane, which is a greenhouse gas that contributes to global climate change.

The city considered building a power plant itself to use the gas using public–private partnership (PPP) based solution. Therefore, a request for tender was released for a private partner to finance, design, build, own and operate a beneficial-use facility.

The 20-year PPP contract was based on the most highly evaluated proposal. The private partner financed and constructed the cogeneration plant, which uses the landfill gas as fuel to generate enough electricity (7.4 MW per year) to supply 4,000 to 5,000 local homes. The power is sold by the private partner to a provincial utility, BC Hydro.

Proceeds from the sales of power and thermal energy go to the private partner, minus a 10 per cent royalty paid to the city.

Heat from the power generation process is recovered as hot water, which is sold by the private partner to a 32-acre tomato greenhouse complex adjacent to the plant, where the water is used for heating purposes.

Vancouver makes no payments to the private partner, but guarantees the provision of landfill gases for the 20-year duration of the PPP contract.

The private partner's investment was approximately CAN 10 million.

Using the landfill gases in this manner, rather than burning them, results in a further reduction of greenhouse gases, equating to the removal of 6,000 vehicles from Canada's roads.

Source: United Nations Economic Commission for Europe. 2012. *Case Studies in Green Technology PPP Projects: Waste to Energy*. Available at https://www.unece.org/fileadmin/DAM/SPECA/documents/kdb/2012/Seminar_Kyrgyzstan/Smith1.pdf.

121. **Cooperative investment financing for low-cost energy and energy security.** Cooperative financing may be a noteworthy option to explore for some waste-to-energy technologies that promise low-cost energy or the proximity of energy sources to otherwise isolated or remote communities. Likewise, new financing models are needed for accessing groundbreaking technologies such as a hydrogen-based economy.

122. **Invest in pilot projects and demonstration projects.** There are perceived or real risks with transferring technologies from one setting to another, for example from a larger scale to a lower scale, from a setting where the feedstock is rich in plastics to a setting where the feedstock is characterized by higher biodegradables or from a cold climate to a warm climate. To tailor the technology and adapt it to local conditions, grants and subsidies are needed to support pilot and demonstration projects.

123. **Looking at the impact of the investment on the economy as a whole.** In order to roll out and scale up investment into waste-to-energy solutions, the sustainable development co-benefits of projects, such as the benefits of biochar on soil rejuvenation and carbon sequestration, the positive impact on switching from fossil fuel to renewable sources and the opportunity to develop businesses based on the new energy stream, should be considered.

124. **Capacity-building is essential for scaling up and rolling out.** Waste-to-energy technologies require a new set of skills from those implementing and managing these projects, be it farmers, industries or authorities or a combination of these. There is a need for capacity-building and transfer of know-how among the different stakeholders and between countries. Technology suppliers are key in the capacity-building process.

B. Supply chain redesign and industrial waste reuse and prevention solutions

125. **Invest in the development and implementation of innovative technologies.** Government and business need to join forces to invest in technologies such as smart solutions for a circular economy, eco-design and bioengineering and green chemistry to replace toxic materials that are not recyclable or reusable.

126. **Look for symbiosis in systems.** Cities and industrial parks are systems that provide opportunity for symbiosis, sharing, cost-efficiency, and material and energy efficiency.

127. **Improve metrics in order to improve management and increase transfer of technology.** The practice of measuring waste prevention and supply chain redesign and industrial waste reuse is still in its infancy and is being developed within companies and industries that have implemented various solutions in this respect. There is a need to standardize metrics to be able to manage and measure progress and transfer know-how and technologies in a meaningful way across sectors and geographic areas. Ultimately measurements connecting material extraction, material flows and waste flows in one circular measurement system will be the aim.

128. **Design ambitious policies connecting material efficiency, energy efficiency and skills development.** Policy is struggling to balance interests as technologies are evolving fast. The circularity principle needs to be introduced into policies through ambitious prevention, reuse and recycling targets and instruments such as extended producer responsibility and end-of-waste definitions. Streamlining circularity in all aspects of policies,

including fiscal policy, energy policy, material extraction industries and manufacturing is needed.

129. **Create a level playing field in terms of policy to reduce leakage of waste and polluting technologies.** Unless regulations are streamlined, for example regarding end-of-waste criteria or best available technologies in terms of resource efficiency, there is a threat of continued leakage of waste from developed countries to developing countries. At the same time, the difference in policies is giving industries in certain countries more competition.

130. **Encourage collaboration, co-creation, co-delivery and open source-sharing.** In the new paradigm of circular economy technology development, both policy development and monitoring need collaboration. Instruments for this are digital and other platforms, councils, coalitions, matchmaking, incubators, and formal and informal ways to reach out and consult in order to support social innovation. Sharing knowledge on technical and other innovation is key for advancement.

131. **Transform business models to push the transformation of the economy.** Business models are changing in some key ways that are very relevant for resource efficiency and for supply chain redesign and industrial waste reuse and prevention. Products are increasingly turning into services, since more people want to have comfortable and accessible services (for instance, service built around the concept of sharing bicycles and cars) rather than owning assets that burden mobility. Sharing is becoming a new way to enjoy a high level of utility from the same assets and resources. Waste and material handling is increasingly paid by key performance indicators for efficiency rather than by tonnes handled. Taking over these principles and implementing them across contracting organizations in various industries has the potential to trigger important changes.

132. **Encourage investment in traditional research and development.** Across sectors that have a vast material footprint and therefore also high GHG emissions, research and development into sector-specific solutions for supply chain redesign, industrial waste reuse and prevention should be encouraged by economic instruments or national support programmes.

133. **Provide patient capital.** A new investment paradigm is needed to support innovative entrepreneurs to scale. This type of investment needs to be mid-size soft loans or guarantees or other suitable financial instruments that are more than the small seed money that funds pilot projects but smaller than the financing currently available from the development banks and agencies.

134. **Work for value rather than short-term return on investment.** Short-term returns are not possible in system redesign and innovation; therefore, a wider view is needed. Similar to waste-to-energy technologies, but perhaps even more pronouncedly so in the case of these strategies, a need to take into account co-benefits, including an increase in resource security, a reduction of pollution and related public health risks and a reduction of conflict and migration risks should be considered to make a compelling case for these developments.

135. **Create demand-side efficiency.** Awareness, consumer pressure and living a more circular life at home has huge potential in energy and material efficiency. Changing lifestyles and consumption patterns, green procurement and circular procurement are equally important to the supply-side changes happening in the production cycle and supply chain.

136. **Build capacity for new skills in changing industries and emerging new sectors.** The range of skills needed in the circular economy is wider than ever. The focus on service-based industry and customer care is likely to offset the negative influence on the workforce from digitalization and automation developments. However, for the workforce to be able to meet the new challenges, continued capacity-building and training are needed as economies transition towards circularity.

C. Actions to be considered in the short term (up until 2020)

137. Table 7 includes recommendations that target the actions that are likely to be easily achieved and to result in large mitigation impacts. All listed activities need stakeholder support and consultation. They are assigned in terms of main implementing stakeholder to

one entity who will probably need to take the initiative and lead the cooperation and consultation, but will carry out the action in cooperation with others.

Table 7
Actions for the short term (up until 2020)

Leading implementing partners	*Practical action points to achieve short-term results*
Governments	• Facilitate the permitting process for waste-to-energy projects and grant access for feeding energy to the grid • Introduce favourable feed-in tariffs or a green certificate system for waste-to-energy technologies • Introduce economic and policy instruments to promote the use of compost as fertilizer • Analyse and streamline policies to the strategies of the circular economy, including fiscal policy, energy policy and waste management policy • Investigate the need for and provide key financial instruments for the circular economy and innovation in the circular economy, for example guarantees and patient finance • Launch initiatives to look for synergies and symbiosis across sectors, such as combining feedstock from different sources for waste-to-energy and enhancing industrial symbiosis
Local authorities	• Engage in capacity-building activities to enhance capacity to develop and manage complex projects • Improve waste management data collection and reporting • Implement good collection systems to increase the quality of waste materials and the feedstock to waste-to-energy technologies • Take the initiative to attract private investment and develop inclusive business models for circular economy projects
Private sector technology providers	• Invest in scaling and adapting waste-to-energy technologies to the needs of clients from the developing world • Allocate financial resources to traditional research and development and to disruptive innovation
Commercial financing sector, including banks and private investment funds	• Develop project-based financing instruments for waste-to-energy projects and establish high-knowledge specialized departments for waste-to-energy projects • Align financing instruments to the special needs of the sector, namely ensure smaller-scale financing for smaller-scale projects
Expert organizations, research, academia	• Develop and standardize metrics for a circular economy • Develop ways to enhance the quality of waste generation data through innovative solutions to enable a feasibility assessment of investment options • Develop innovative finance instruments and inclusive business models for a circular economy
International organizations	• Finance or co-finance pilot projects and demonstration projects for waste-to-energy and for supply chain redesign and industrial waste reuse and prevention • Disseminate learning and knowledge using case-based studies • Build capacity in emerging sectors • Raise awareness for boosting a demand-side circular economy
UNFCCC constituted bodies and mechanism	• Make the circular economy a higher priority and a sector with high mitigation potential • To achieve low-carbon and climate-resilient development, facilitate and promote (1) the accelerated transfer of environmentally sound technologies; (2) the formulation of conducive policy and legal and regulatory frameworks; (3) capacity-building and (4) the financial flows tailored to the needs of developing countries
Civil society and the public	• Engage in consultations related to circular economy policy and initiatives • Participate in delivering circular economy solutions

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