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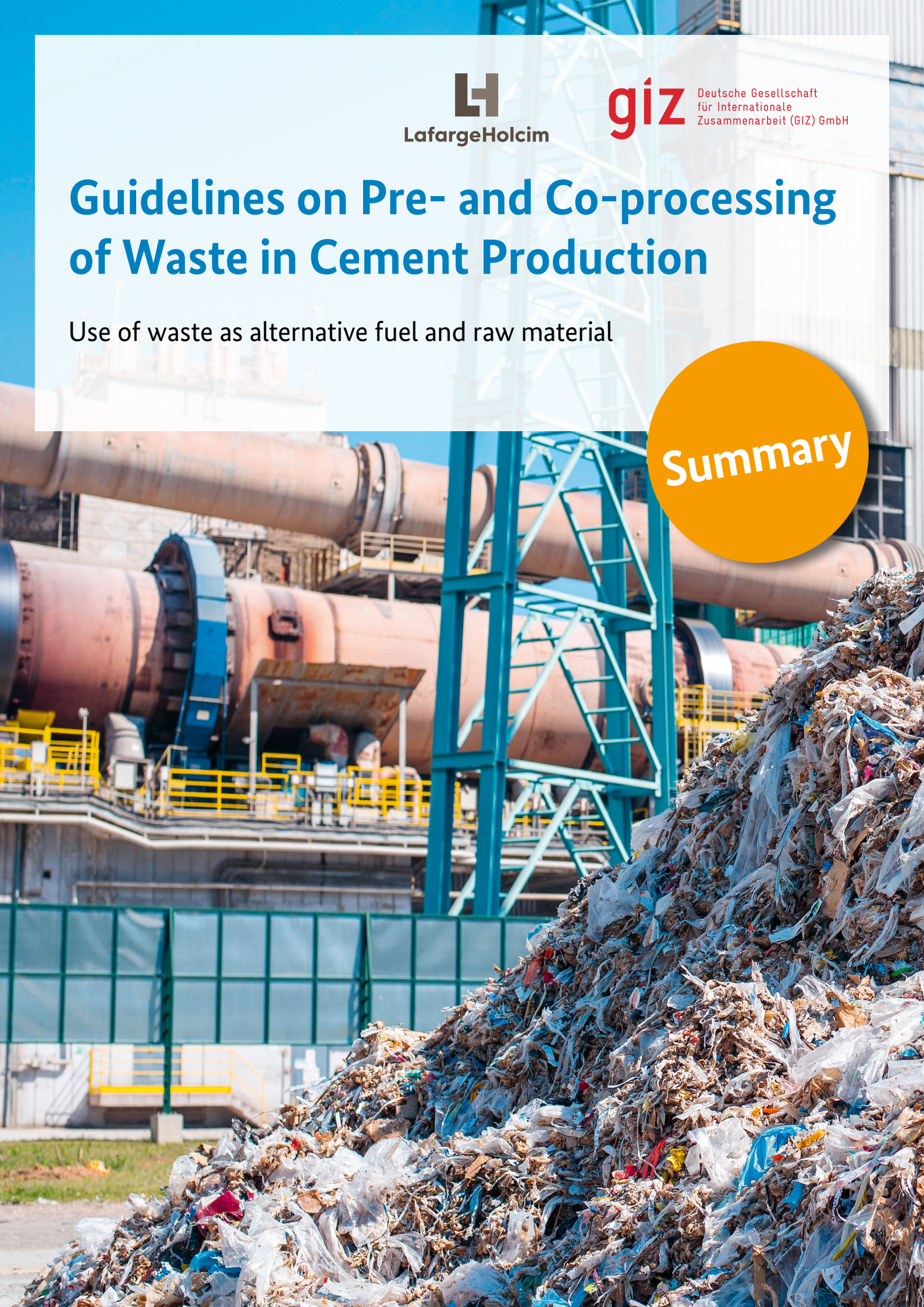
Guidelines on Pre- and Co-processing of Waste in Cement Production

Use of waste as alternative fuel and raw material

Summary



Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)

S. Blume
Friedrich-Ebert-Allee 36 + 40
53113 Bonn
Germany
T +49 228 4460 – 0
E info@giz.de
I www.giz.de

Holcim Technology Ltd

A. Pandey
Im Schachen
5113 Holderbank
Switzerland
T +41 58 858 52 82
E groupsd@lafargeholcim.com
I www.lafargeholcim.com

University of Applied Sciences and Arts Northwestern Switzerland, School of Life Sciences Institute for Ecopreneurship

D. Mutz, D. Hengevoss
Hofackerstrasse 30
4132 Muttenz
Switzerland
E dieter.mutz@fhnw.ch
E dirk.hengevoss@fhnw.ch
I www.fhnw.ch

Summary
Guidelines on Pre- and Co-processing of Waste in Cement Production

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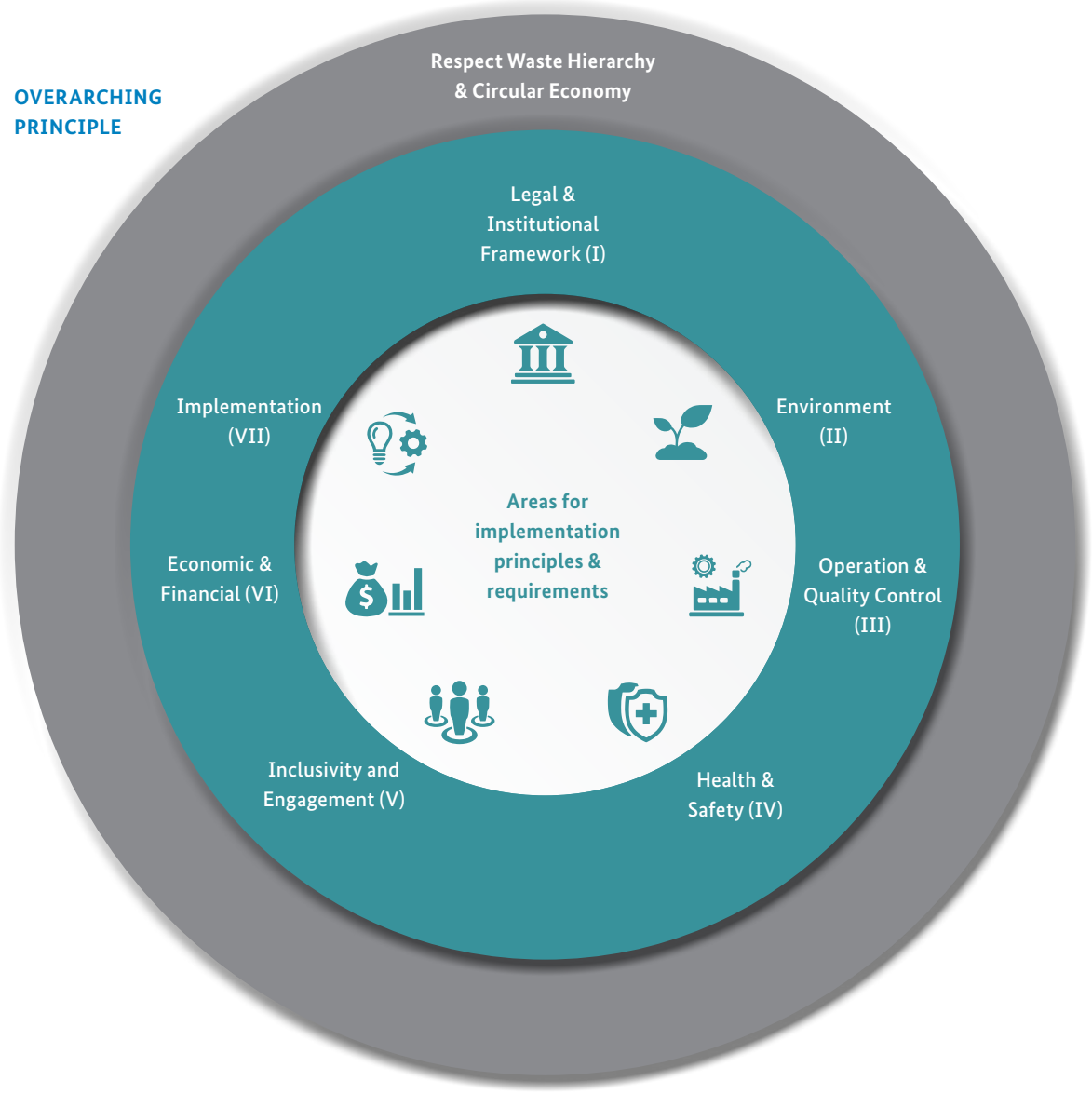
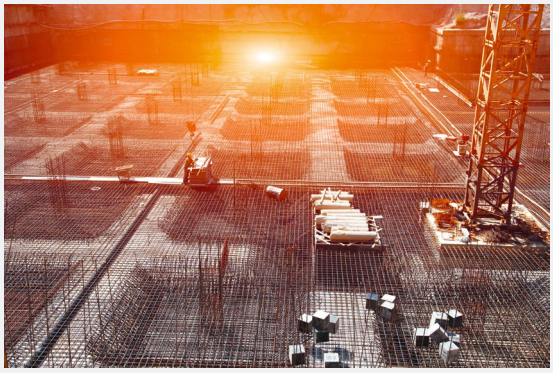
In 2020, GIZ, LafargeHolcim and University of Applied Sciences and Arts Northwestern Switzerland published updated guidelines on pre- and co-processing of waste in cement production. Originally published in 2006, the Holcim-GIZ guidelines became a key reference document for the waste and cement sector. The updated guidelines provide further practical guidance and detailed principles for applying pre- and co-processing in an environmentally sound and safe way. These can be downloaded in full in multiple languages at *www.geocycle.com/guidelines* and *https://mia.giz.de/qlink/ID=247254000*. This document provides an overview of the key messages from the guidelines.

The primary target groups for the guidelines are decision makers in the waste and cement sector, while decision makers in government, non-governmental organizations (NGOs) and civil society organisations remain a key audience. The main objective of these guidelines is to improve waste management by offering updated and new objective information about pre- and co-processing of waste materials in the cement industry. They contain knowhow and practical experience gained from implementing pre- and co-processing, as well as recommendations on environmental, social, technical, financial and legal requirements. Although they cannot be regarded as binding law, their application can enhance broad acceptance of pre-processing of waste materials and co-processing of Alternative Fuel and Raw material (AFR) in cement plants. The guidelines promote an approach that aims to reduce existing waste problems by encouraging the use of waste as an alternative source for primary energy and virgin raw materials in cement production. Wherever possible, the concepts of resource efficiency, circular economy, recycling and reuse must be given first priority in the local context.

Principles of the guidelines





Overarching principle 	**Respect Waste Hierarchy & Circular Economy** • Pre- and co-processing shall respect the waste hierarchy and can be regarded as a contribution to the circular economy.
Principle area I 	**Legal & Institutional Framework** • Compliance with all relevant laws and regulations has to be assured. • Pre- and co-processing shall be in line with relevant international agreements (e.g. Basel and Stockholm Conventions). • Effective monitoring by a qualified environmental regulator, that has sufficient institutional capacity shall be ensured. • Country-specific requirements and needs shall be reflected in regulations and procedures. • If a local legal framework for pre- and co-processing is not existent and/or inconsistent, international best practices shall be applied and build-up of the required capacity and the set-up of institutional arrangements ensured.
Principle area II 	**Environmental Aspects** • Prevent or keep additional emissions and other negative effects on the environment from pre- and co-processing at a minimum. • Emissions to air and water from co-processing shall not be higher than from cement production without co-processing. • The cement products (concrete, mortar) shall not be abused as a sink for potentially toxic elements (e.g. heavy metals).
Principle area III 	**Operation & Quality Control** • Only appropriate waste streams shall be selected. These shall be pre-processed to ensure quality control, proper handling and stable kiln operation during co-processing. • Companies engaged in pre- and co-processing must be qualified. They shall control and monitor inputs and relevant parameters of their production processes on a regular basis. • The quality of the cement products (concrete, mortar) remains unchanged.
Principle area IV 	**Health & Safety** • Companies active in pre- and co-processing shall establish appropriate risk controls to provide healthy and safe working conditions for employees and contractors. • Have good environmental and safety compliance records in place as well as personnel, processes, and systems committed to protecting the environment, health, and safety.
Principle area V 	**Inclusivity & Engagement** • Companies active in pre- and co-processing shall engage regularly and communicate transparently with the public, relevant authorities and other stakeholders. • Country specific or local needs and different cultural environments shall be taken into account when implementing pre- and co-processing. • Companies engaged in pre- and co-processing shall consult and collaborate with actors in the existing local waste management value chain, including informal waste workers.
Principle area VI 	**Economic & Financial Aspects** • Pre- and co-processing projects are based on a financially sustainable business model, which brings value to all involved stakeholders and local communities. • Financial mechanisms shall be in place to ensure that interventions have financing covered in the medium to long term.
Principle area VII 	**Implementation** • Monitoring and auditing systems need to be in place to enable successful implementation • Capacity building and training at all levels is essential.

The guidelines provide requirements and detailed info for each principle

Key messages of the guidelines

The implementation of Pre- and Co-processing can be effective contribution to local waste management when following the principles set out in the guidance:

- Pre- and Co-processing
  - cannot solve the global waste challenge alone, but can provide an environmentally sound solution as part of an integrated waste management strategy require a robust and adapted legal and institutional framework.
  - can support waste management, substitute fossil fuels and primary raw materials in cement production, and eliminate harmful substances from the circular economy.
  - respect the waste hierarchy and do not contradict it when these guidelines are followed. In this context, it can be classified as a technology for energy recovery and mineral recycling.

- The level of local economic development, environmental consciousness, political priorities, good governance or cultural habits influence the dynamics and the time it takes to modernise the waste management system. The implementation of pre- and co-processing must be seen as a part of this change process and will progress differently from country to country.

- The guidelines should be implemented on the basis of a spirit of open and transparent cooperation between the public and private sector. As this will not happen overnight, a gradual phasing-in is needed.

- All involved stakeholders must have at least a basic understanding of waste management and those who are directly involved in operational procedures, supervision and monitoring must also have specific knowledge on pre- and co-processing.

- The driving force for the introduction of pre- and co-processing in accordance with these guidelines can be national waste management and cement associations, individual cement companies or the public sector. Whoever promotes this activity should do it in a transparent manner and within a well-defined time horizon.

- As populations and incomes increase across the world, so do waste management problems, and so does the need for more cement and concrete for housing and infrastructure. The properly managed use of wastes as fuels and raw materials in cement kilns can help manage wastes while reducing the environmental impact of cement production.

What is pre- and co-processing?

Pre-processing refers to preparing waste to make it suitable for co-processing in cement kilns. Waste is converted from an unwanted discarded material into a useful resource, so-called Alternative Fuel and Raw Materials (AFR).

Photo:
Alternative Fuel and Raw Materials.

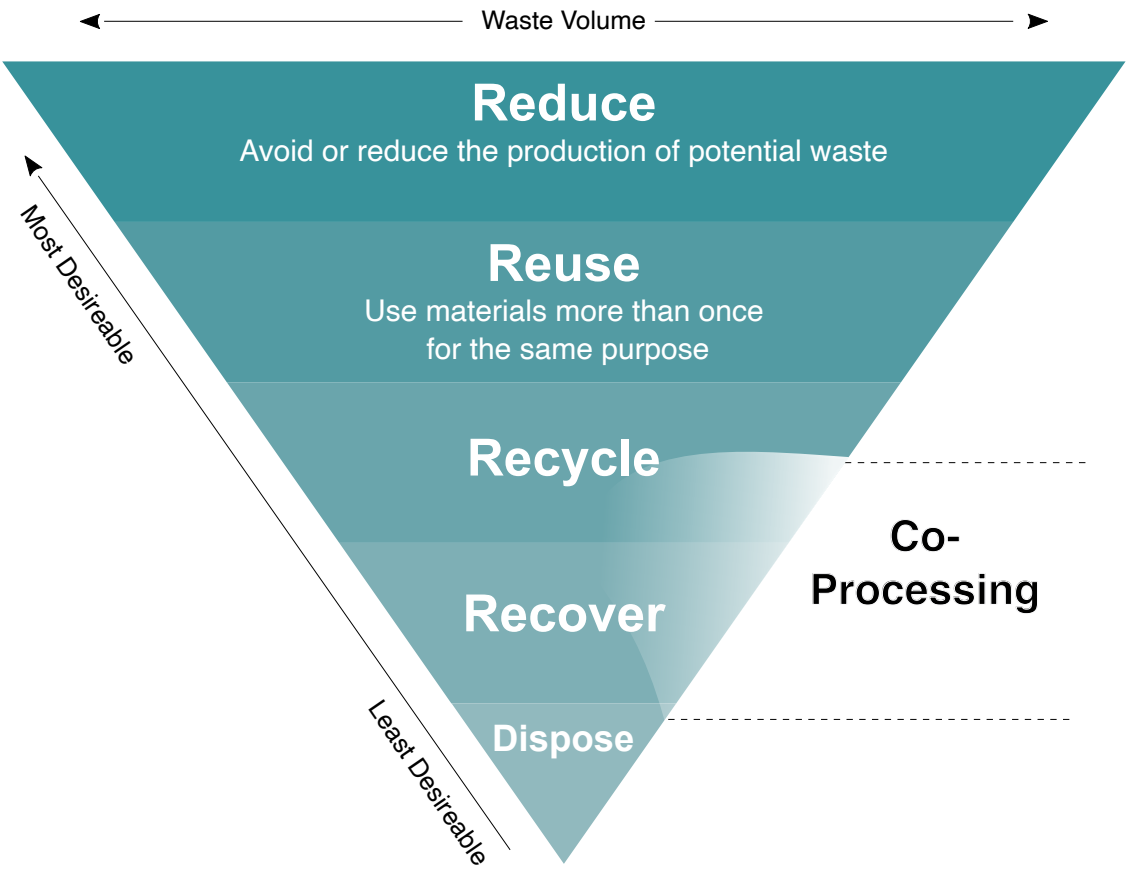
***Alternative Fuels and Raw Materials* (AFR):**

AFR refers to selected waste and by-products that can be co-processed in cement production. It contains a recoverable energy content (calorific value), which replaces energy needs from a portion of conventional fossil fuels (Alternative Fuels – AF) and useful minerals such as calcium, silica, alumina, iron and sulfur that replace natural raw materials in clinker production or mineral components in cement production (Alternative Raw Materials (AR).

Co-processing refers to using AFR in the cement production process at suitable feed-in points in a controlled manner, where it burns as fuel and provides raw material. This enables substitution of primary fuels (coal, petroleum coke, and natural gas) and raw materials, recovering energy from the waste and recycling its mineral content. Only qualified waste materials may be used for this process.

How does it contribute to the waste management system?

Pre- and co-processing represent a structural contribution to the improvement of waste management in low- and middle-income countries by providing an important waste management solution and at the same time reducing the incidence of open burning, marine littering and disposal at uncontrolled dumpsites. The use of pre- and co-processing can support waste management, substitute fossil fuels and primary raw materials in cement production, and eliminate harmful, hazardous substances from the circular economy.



Waste management hierarchy. Co-processing overlaps with the levels recycle, (energy-) recovery and for selected waste with dispose.

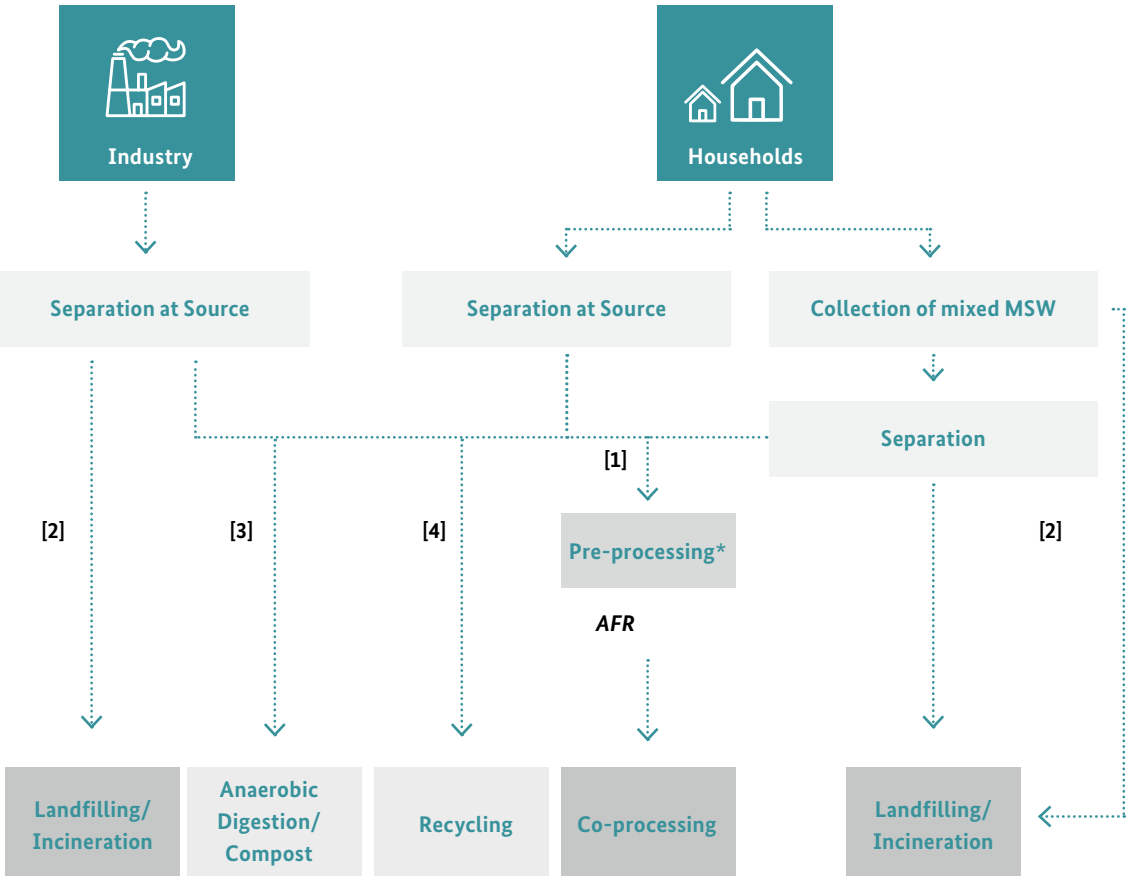
The waste hierarchy is a broadly accepted global framework for policy makers on designing waste management systems. The figure illustrates the position of pre- and co-processing in comparison to other waste management options. Materials that can be recycled in a closed loop should not be accepted for co-processing, which instead provides a complementary solution for non-recyclable materials.

Often waste fractions suitable for closed-loop recycling are separated at source or sorting stations after waste collection in most industrialized countries, however, in other countries the waste fractions with a market value suitable for closed-loop recycling are more often separated by informal waste pickers (e.g.PET). Only very few waste types (e.g. whole tires) can go directly into the cement plant for co-processing without further treatment. All other wastes suitable for co-processing must first be transferred to dedicated pre-processing facilities where they can be transformed into AFR.

Pre- and co-processing is not a standalone solution to all waste management needs, but it plays a role in an integrated waste management system *as shown in the figure below*. For instance, co-processing has become a well-established and widely accepted waste solution in Europe with some cement plants managing to substitute up to 100% of conventional fuels with alternative fuels.

Compared with other waste-to-energy technologies such as waste incineration, co-processing has the advantage that it can be incorporated into existing cement production facilities and does not require major investments in new waste management infrastructure.

Integration of pre- and co-processing in the management of waste from industry and households.



* selected industry wastes such as waste oils and solvents do not require pre-processing

Legend:
[1] Non-recyclable waste
[2] Non-recyclable and non-applicable for co-processing
[3] Biomass
[4] Recyclables

Conditions:
[1] - High calorific value
- Raw material substitutions
- Secure thermal treatment of hazardous waste

What is its role in a circular economy?

The circular economy supports waste prevention, reduction and reuse (including repair) as a first priority, followed by recycling, energy recovery, and as a last resort, disposal. It aims to recover key materials necessary for society, whilst simultaneously enabling economic growth and innovation. Pre- and co-processing can make important contributions to the circular economy transition through:

- Reliable elimination of harmful substances and their residues through controlled high processing temperatures, following a consensus that it is better to destroy them than allow them to cycle through a circular economy production system.
- Being the best use of residual waste when closed-loop recycling is not an environmentally, technically or economically sound alternative.
- Conservation of primary resources (raw virgin materials and traditional fuels) by replacing them with secondary resources.
- An optimized use of waste through mineral recycling and energy recovery.

How does it help to prevent marine litter?

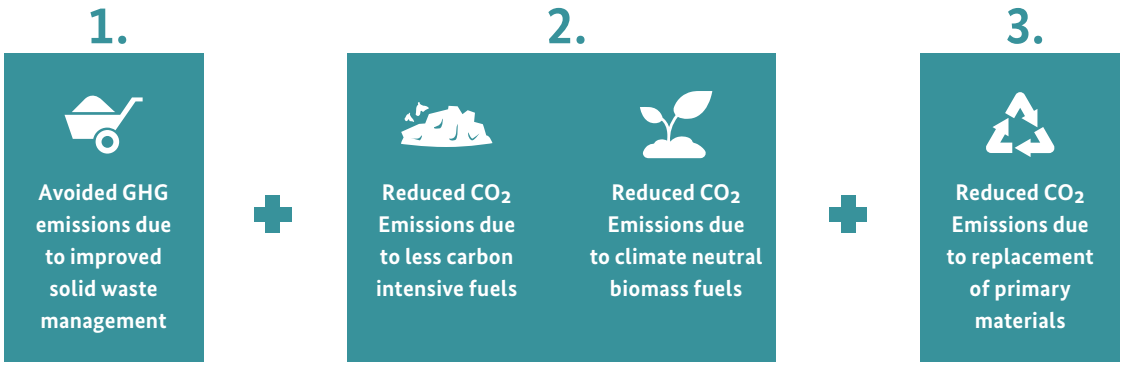
Thirty-eight of the world's fifty largest uncontrolled dumpsites are in coastal areas, many of them overflowing with waste directly into the sea. As moderate-cost options, pre and co-processing of non-recyclable plastic waste can help upgrade waste management systems and reduce uncontrolled disposal and litter that might leak into the environment. This in turn has the potential to reduce or eliminate land-based plastics that find their way into the sea and end up as marine litter.

Photo: Marine litter on beach.

Can co-processing mitigate greenhouse gases?

Producing cement is an energy intensive process requiring ingredients to be heated to a temperature of 1450°C. This high temperature requires substantial combustion of fuels which, together with carbon dioxide (CO_2) emissions from the chemical process reaction, leads to roughly 7% of global anthropogenic greenhouse gas emissions. Typically, 30 – 40% of CO_2 emissions result from combustion of fossil fuels to attain the high operating temperatures needed in the kiln system. The other 60 – 70% are so-called process emissions, arise from the calcination reaction necessary to convert limestone into lime.

The cement industry can play a key role in efforts to decouple resource use and carbon emissions from economic growth. Avoided Greenhouse Gas (GHG) emissions can also be significant, particularly when co-processing forms part of an integrated waste management approach. An example of how such emissions reductions and avoidance can take place is demonstrated *in the figure below*:



1. **Savings through improvement of waste management services:** In low and middle income countries waste is often dumped and burned openly near the source or at landfills – a practice that contributes up to 10% to global warming through short lived climate pollutants. In other cases, collected waste does not reach recycling, recovery or controlled disposal facilities, but is sent to uncontrolled dumpsites or landfills instead. Here the organic part of the waste decomposes anaerobically and produces significant levels of methane (CH_4), a GHG with 25 times the global warming potential of CO_2.

   Where suitable systems are set up to segregate at source and remove the organics from the waste stream, major reductions of GHG emissions can be achieved through composting, recycling and co-processing of the non-recyclable fraction of Municipal Solid Waste, which is pre-processed into a combustible AFR. Co-processing of waste in cement kilns avoids open burning and also enables indirect GHG emission reduction through treatment of organic waste fractions which otherwise would have anaerobically decomposed at landfills or dumpsites.

2. **Emissions reduction due to substitution of fossil fuels:** Many countries continue to use coal or petcoke as the main fuel for cement production due to its low price and availability, despite the fact that coal has the highest carbon emissions. Direct emission reductions from co-processing AFR depends on the emissions factor and biomass content, which varies for different fuel types. Agricultural residues and other fuels with high biogenic carbon content typically have high emission factors, however, these can be considered as carbon neutral due to the absorption of carbon dioxide during their growth. Alternative fuels derived from waste materials such as waste oil and non-recyclable plastics have varying emissions values, which are usually lower than traditional fossil fuels. Increasingly, fuels are used which contain both fossil and biogenic carbon, e.g. pre-treated industrial wastes (containing non-recyclable plastics, textiles, paper etc.), waste tires (containing natural and synthetic rubber), or RDF from MSW which contains also a significant biogenic carbon content.

3. **Reduced emissions due to replacement of primary raw material:** co-processing incorporates an inert material component from the waste into the clinker structure, substituting other primary raw materials. From a climate and resource efficiency perspective, secondary or alternative raw materials tend to be favorable compared to primary raw material.

Working with the informal waste sector

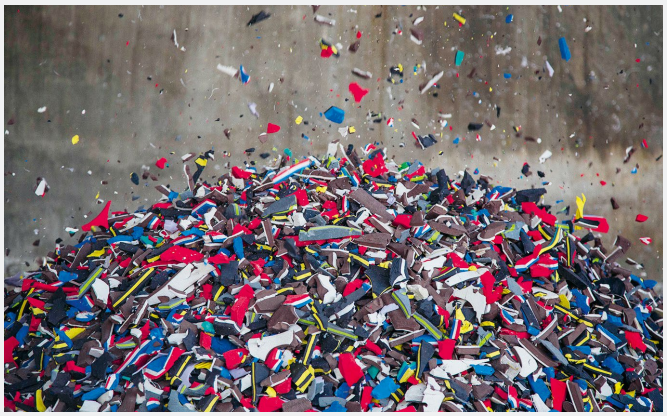
Informal recyclers and waste pickers are part of the waste management landscape in almost all low and middle income countries. They can represent as much as 1% of the total population and are usually active at the lowest value part. Many studies have shown that the informal waste sector can contribute significantly to municipal waste management, but if not integrated effectively can also negatively affect local waste management systems. Informal waste collection and recycling activity can contribute to recycling rates of 20 to 30% in low-income countries, and saves local authorities around 20% of what they would otherwise need to spend on waste management.

In relation to pre- and co-processing, the discussion of what happens to the informal sector remains relatively new. It has become the consensus that informal recyclers cannot be ignored while attempting to improve waste and resource management. A number of synergies for cooperation with the informal sector exist mainly in the field of pre-processing of waste. Co-processing happens at the cement plant and requires stringent employment rules, regulations and standards.

- Informal recyclers in emerging economies can in some instances be the only local recycling experts experienced in separate collection or extraction of recyclables.
- Studies indicate that 20% of active waste pickers might choose to leave informality if given the right support. Giving them training and employment could be an option to exit informality and enter regular employment.
- Collaboration strengthens the “social license” of an operator as the quality of life of communities around pre- and co-processing operations is improved.

How does waste become alternative fuel and raw material

Most waste streams are too heterogeneous in their chemical composition and physical properties to be directly co-processed at the cement plant. They need to undergo initial treatment, so-called pre-processing.



Depending on the physical properties and chemical characteristics of the waste; mechanical, biological or physico-chemical processes are applied to transform the waste into a resource according to the requirements and acceptance criteria of the cement plant. Finally, during co-processing at the cement plant the mineral content (i.e. Ca, Al, Fe, Si) of the waste gets completely recycled as raw material without creating any residues, replacing minerals that would otherwise have come from primary resources. The organic content of the waste is recovered as thermal energy, substituting conventional fuels.

A wide variety of residual waste materials can be successfully used for pre-processing into AFR and co-processing in cement kilns:

	Municipal Solid Waste	Industrial Hazardous Waste	Industrial Non-Hazardous Waste	Biomass Residues	Alternative Raw Materials
Waste Type	• Sorted municipal waste • Dried municipal waste	• Oil & Gas • Chemicals • Pharma • Automotive • Liquid	• Trade rejects • FMCG • Packaging • Tires • Fiscal destruction	• Husks (rice, soya, etc.) • Wood • Seeds • Bagasse	• Iron, aluminum • Silica, clay, gypsum • Fly ash, slag • Construction demolition waste
Typical customers	• Municipalities • Waste management companies	• Local and multinational companies	• Local and multinational companies	• Farmers, plantations, millers • Brokers, traders	• Local and multinational companies
Waste Generation	• 1,300 Mio Ton	• 200 – 400 Mio Ton	• 1,200 Mio Ton	• 140,000 Mio Ton	• 800 – 1,000 Mio Ton

How to select suitable waste streams for co-processing?

In order to operate in a safe and environmentally sound manner, the waste selection criteria should be specified and the use of certain types of waste material should be restricted. The waste selection process in pre- and co-processing considers the suitability, most favorable treatment option according to the waste hierarchy, fulfillment of requirements (legal, environmental, operational and health & safety) of pre- and co-processing facilities, acceptance criteria of the cement plant, impact on the production quality of clinker, and affordability in relations to the costs of cement production. Waste and AFR quality and emissions data not only form the basis for ensuring compliance to authorities, but also for discussions with external stakeholders to address local concerns.

Aspects to consider for AFR selection criteria

- National environmental policies
- Efforts to harmonize supra-regional environmental laws and standards
- Pollutant levels in traditional fuels and raw materials
- Available waste treatment alternatives
- Toxicity level of pollutants in waste
- Requirements for cement quality
- AFR quality and product quality control
- Emission monitoring and reporting.

Photo:
AFR Quality Control.

What should be excluded from co-processing?

Due to chemical composition, material properties or potential hazards, some wastes may be unsuitable for pre- or co-processing and should not be used as this could jeopardize the safe operation of a pre-processing facility or a cement plant and may lead to significant environmental impacts. The following list of waste materials should not be considered for pre- and co-processing:

- Radioactive waste
- Waste containing asbestos
- Explosives and ammunition
- Self-reactive thermally unstable compounds
- Anatomical, infectious and health care waste
- Waste Electrical and Electronic Equipment
- Entire batteries.

Why is cement production technically suitable for co-processing of waste?

The high temperature conditions in the cement kiln gives co-processing inherent advantages that prevent the formation of dangerous compounds or destroy these, whilst at the same time binding minerals into the cement product, avoiding problems of residual hazardous wastes.

Some of these advantages are:

- Internal gas cleaning due to alkaline conditions and intensive mixing of exhaust gas and raw meal reduces emissions of acidic components (SO_2, HCL & HF) and most other potentially toxic elements (PTEs).
- The short retention time of the exhaust gases in the temperature range known to lead to the formation of dioxin and furans (PCDD/F) prevents the formation of these secondary polluting compounds.
- The process is resistant to the production of nitrogen oxide (NOx) emissions and can even reduce their formation due to flame cooling in the rotary kiln by the higher moisture content and excess air requirement of alternative fuels.
- Complete destruction of organic pollutants due to high process temperatures, oxidizing conditions and long residence times.
- High energy recovery efficiency (generally in the range of 70 – 80%) compared to waste incinerators (average efficiencies of 26%, however incinerators recovering combined heat and power achieve similar efficiencies as cement kilns).
- High levels of mineral recycling as no ashes or other residues are left behind. All mineral components, non-volatile Potentially Toxic Elements (PTE) and other trace elements (e.g. Cl, S) are fully incorporated into the matrix of the clinker.

What to consider when applying it – how to do it right?

The overarching principle is to be considered as a pre-condition for pre- and co-processing. It is of paramount importance that pre-and co-processing respects the waste hierarchy / circular economy and is implemented in a safe and environmentally sound way. Therefore, the guiding principles *(see page 4)* must be followed to ensure successful implementation. These principles and requirements form the backbone of the guidelines.

Countries considering pre- and co-processing need appropriate legislative and regulatory frameworks. National laws should define the basic principles under which pre- and co-processing takes place and define the requirements and standards. These should be the basis for the permitting process. If no specific regulations exist, the plant operator should apply international best practice under the general environmental law and international standards should serve as a reference.

Baseline assessments, including environmental & social impact assessments (EIA and SIA), local waste management and value chain assessments should be done to confirm compliance with environmental and social standards. Some wastes should never be pre- and co-processed; these range from certain health care wastes to explosives and radioactive waste. Generally waste streams need pre-processing before they can be co-processed, and approaches to AFR use should take account of the need to effectively regulate and manage these pre-processing plants. Following certain basic rules assures that pre- and co-processing does not have negative impacts on emissions, nor harm the quality of the cement produced. These include feeding AFs into the most suitable zones of the kiln, feeding materials that contain elevated levels of volatile organics into the high temperature zone only, and avoiding materials that contain pollutants kilns cannot retain, such as mercury. Emissions must be monitored, some only once a year and others continuously.

Operators of pre-processing facilities and cement plants using AFR shall ensure traceability from reception up to final treatment. Transport of wastes and AFR must comply with regulations. Companies engaged in pre- and co-processing must be holding proper permits and the quality of the cement that is produced should remain the same. Proper handling and storage of AFR on these sites should be done to prevent spillage as well as contamination of natural resources. All relevant processes that are carried out during pre- and co-processing shall be measured, recorded and evaluated continuously. The impact of AFR on the total input of volatile elements such as chlorine, sulfur, or alkalis shall be assessed carefully prior to AFR acceptance, as they may cause operational problems in the cement kiln system. Therefore quality monitoring of AFR is also important; each batch of AFR should be inspected and/or tested prior to being delivered to pre- and co-processing sites.

Plants must have developed, implemented and communicated to employees adequate spill response and emergency plans. For start-up and shut-down AFR use should be excluded. Strategies for dealing with AFR must be documented and available to plant operators. Plants need well planned and functioning quality control systems, as well as monitoring and auditing protocols. Risks can be minimized by properly locating plants in terms of environmental setting, proximity to populations and settlements, and the impact of logistics and transport. Plants will require good infrastructure in terms of technical solutions for vapors, odors, dust, infiltration into ground or surface waters, and fire protection.

Health and Safety is one of the major aspects while handling AFR during pre- and co-processing. All aspects of using waste and AFR must be well documented, as documentation and information are the basis for openness and transparency about health and safety measures, inside and outside the plant. Safe working conditions and environment shall be provided by establishing proper risk controls. Each pre- and co-processing site shall develop, implement and communicate a detailed emergency response plan to ensure effective and rapid response. All working personnel and visitors shall be trained regularly. Understanding risks and how to mitigate them are keys to training. Training of authorities is the basis for building credibility.

Introducing pre- and co-processing requires open communication and engagement with all stakeholders. Provide all relevant information to stakeholders to allow them to understand the purposes of co-processing, the context, the functions of parties involved, and decision-making procedures. Open discussions about good and bad experiences are part of transparency, leading to corrective actions. Be credible and consistent, cultivating a spirit of open dialogue and respect for differing cultures. Communication should start early and never stop. Community advisory panels can support exchange on a regular basis.

To be successful in the long run, financing of pre- and co-processing projects must be assured, and can be supported through appropriate waste legislation which respects the waste hierarchy, making landfilling or open dumping unattractive options. Before considering pre- and co-processing of MSW as an opportunity, municipalities should be able to fully cover the costs for MSW collection and disposal in a controlled landfill; further financial means to cover additional costs should be easily accessible. In the long-term a fee for waste generators based on the polluter pays principle is desirable, whereas current management costs may be primarily covered from the municipality budget. In particular, increasing the fee for landfilling can make other waste management options more feasible.

A financially sustainable business model is crucial for any pre- and co-processing project. In ideal cases, the savings from the substitution of fossil fuels would be enough to offset the costs of other steps in the pre- and co-processing value chain, however this is rarely the case: A waste management fee must often be paid for by the waste generator. Municipalities, waste management and cement companies need a common understanding of the financial implications of pre- and co-processing in order to establish co-processing as a long-term waste management option. It must be understood that proper pre- and co-processing activities incur substantial investment and operational cost.

In these guidelines the bar has been kept high in terms of environmental, social and health and safety standards, but they are realistic and achievable. Ambitious targets are needed in order to achieve goals (e.g. the Sustainable Development Goals). However, one cannot expect that the public sector in any country or each and every cement plant operator or waste handling company anywhere in the world can implement all the proposed standards straight away. To achieve the proposed standards, a stepwise implementation and country specific (phasing) program or action plan is required, which ideally represents a consensus (reflecting the enhanced cooperation) between the public and private sector. Some low- and middle-income countries will need capacity building help on this before launching AFR programs.

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
Friedrich-Ebert-Allee 36 + 40
53113 Bonn
Germany
T +49 228 4460 – 0
E info@giz.de
I www.giz.de

In Cooperation with
LafargeHolcim
Im Schachen
5113 Holderbank
Switzerland
T +41 58 858 52 82
E groupsd@lafargeholcim.com
I www.lafargeholcim.com

University of Applied Sciences and
Arts Northwestern Switzerland
School of Life Sciences
Institute for Ecopreneurship
D. Mutz, D. Hengevoss
Hofackerstrasse 30
4132 Muttenz
Switzerland
T +41 61 228 55 77
E info.lifesciences@fhnw.ch
I www.fhnw.ch

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Authors
Michael Hinkel (LH), Steffen Blume and
Daniel Hinchliffe (both GIZ).
Dieter Mutz and Dirk Hengevoss
(both FHNW)

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