LafargeHolcim

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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

Use of waste as alternative fuel and raw material

IMPORTANT NOTICE

These Guidelines are addressed to stakeholders and decision makers from the private and public sectors engaged in waste management and cement production. The document offers guiding principles and gives a general orientation concerning the conditions in which pre- and co-processing can be applied. They make certain recommendations and provide certain country-specific experiences, but cannot and should not be used as a template. Each person, legal entity or country, in engaging in pre- and co-processing, must develop its own standards based on international conventions and national and local conditions and must harmonize them with its legal framework. These Guidelines shall not be legally binding nor shall they be construed as constituting any obligation, representation or warranty on the part of the authors or the sender or any technical, commercial, legal or any other advice.

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ABOUT THESE GUIDELINES

These Guidelines are an update of the former GTZ-Holcim Guidelines on Co-processing Waste Materials in Cement Production published in 2006 (GIZ-Holcim, 2006). In the past decade changes took place in the waste and the cement sector and those changes are reflected in the 2nd edition of the GIZ-Holcim Guidelines on Pre- and Co-processing of Waste in Cement Production.

These updated Guidelines result from a joint initiative by the *Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH* (GIZ), Geocycle and *LafargeHolcim* (LH). *LafargeHolcim (LH)* is the global leader in building materials and solutions active in four business segments: Cement, Aggregates, Ready-Mix Concrete and Solutions & Products, with leading positions in all regions of the world. Geocycle, a subsidiary of LH, is a leading provider of industrial, agricultural and municipal waste management services worldwide. GIZ is a German government owned corporation for international cooperation for sustainable development with worldwide operations.

Experts from LafargeHolcim, GIZ and the *University of Applied Sciences and Arts Northwestern Switzerland School of Life Sciences* (FHNW) formed a working group to prepare these Guidelines. External experts from public and private sector gave support and advice. The elaboration of the document was coordinated by the Institute for Ecopreneurship of the FHNW.

The working group authors: Michael Hinkel, Daniel Hinchliffe, Dieter Mutz, Steffen Blume and Dirk Hengevoss wish to express sincere thanks to the collaborating experts from LafargeHolcim, GIZ and FHNW and all who participated by sharing their time, information and insights. Great appreciation is expressed to external reviewers for their time and shared valuable knowledge:

- Prof. D.C. Wilson — Independed consultant and Visiting Professor at Imperial College, London
- Dr. C. Velis — PhD Lecturer in Resource Efficiency Systems at the University of Leeds and leader of ISWA Marine Litter task force
- Dr. A. Scheinberg — Global Recycling & Circular Economy Specialist, Springloop Cooperative, Lead of the ISWA Working Group on Recycling and Waste Minimization
- J. Stuen — Technical director, Waste-to-Energy Agency, City of Oslo and ISWA lead for Waste to Energy Group
- Dr. V. Hoenig — Managing Director and Head of Environment and Plant Technology at VDZ (German Cement Association)

Please cite "GIZ-LafargeHolcim, Guidelines on Pre- and Co-processing of Waste in Cement Production – Use of waste as alternative fuel and raw material"

Foreword

The main objective of these Guidelines is to improve waste management by offering updated and objective information about pre- and co-processing of waste in the cement industry. They contain knowhow and practical experiences gained in implementing pre- and co-processing since the first edition that served as a reference document in international agreements (e.g. Basel Convention for Hazardous Waste Treatment) and adaptation of various national guidelines.

The Guidelines follow common understanding that avoiding and reducing waste is the best way of dealing with current waste problems all over the world. The extension of waste collection to 100% of the population and of waste fractions is notably a prerequisite to manage waste effectively in many countries. However, the Guidelines promote an approach that aims to reduce existing waste problems and at the same time to encourage 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.

Improving waste management will take time. Reaching the status of an effective waste management solution in Europe has taken place over a period of 20-30 years. It has been supported by stringent legislation to monitor quality and emissions. Developing pre- and co-processing as a suitable waste management option requires also time and investments. Rigorous permitting and quality assurance procedures need to be applied.

Pre- and coprocessing respects the waste hierarchy and does 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 key for implementation of these Guidelines and to achieve the maximum benefit from pre- and co-processing of waste in cement production continues to be close collaboration and co-operation between the public and the private sectors. Innovative techniques and technical knowhow are available and will be further developed by the private sector, whereas the public sector should ensure that environmental standards are maintained and health and safety regulations are applied and enforced. In addition ethical business conduct, good governance and social responsibility remain prerequisites for successfully implementing the Guidelines.

Table of Contents

Table of Contents

Index of Tables and Figures

Index of Tables

Index of Figures

Index of Boxes and Case Studies

Index of Boxes

Index of Case Studies

Executive Summary

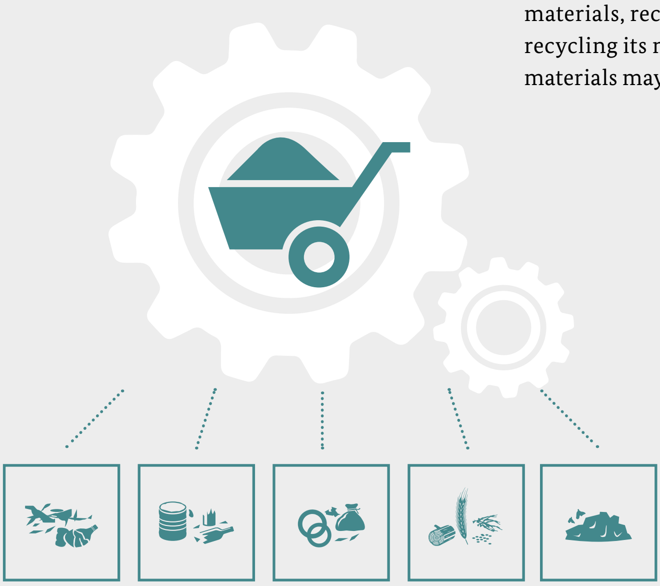
Different types of wastes have been successfully co-processed as *alternative fuels and raw materials* (AFR) in cement kilns in Europe, Japan, USA, Canada and Australia since the beginning of the 1980s. In 2006 the first edition of the GTZ-Holcim Guidelines on Co-processing Waste Materials in Cement Production was published (GIZ-Holcim, 2006), aiming to gather the lessons of these experiences and offer it particularly to low and middle income countries as an option to improve approaches to waste management.

Since then, waste management has earned a much more prominent place on the political agenda. Legal and institutional frameworks for waste management look more and more at the importance of increasing resource efficiency, improving public health, mitigating climate change and avoiding marine litter. These positive developments, as well as the experience gained with pre- and co-processing since the first guidelines were published, contribute to the motivation to publish a revised edition of the guidelines to update technical, institutional, legal and social aspects of the original document, incorporate new ideas and information, and in general to support continuous improvement in the application of pre-processing of waste for co-processing in the cement industry.

While in the first edition of the guidelines the focus was mainly on co-processing of industrial and commercial waste, these updated guidelines now put a stronger emphasis on pre-processing of wastes into AFR, pre- and co-processing of municipal waste and integrating pre- and co-processing into local waste management value chains. More information is given on how pre- and co-processing contributes to the sustainable development goals, its climate relevance, financing and ways to work with the informal waste sector. The original principles have been expanded and grouped with corresponding requirements for implementation. They continue to be based on findings and recommendations from experiences in industrialized and developing countries, as well as from the public and private sector to improve waste management at national and local levels, including attempts by the cement industry to improve environmental performance of cement production.

What is meant by Pre- and Co-processing?

Pre-processing refers to preparing of waste to make it suitable for co-processing in cement kilns. Waste is converted from an unwanted discarded material to a useful resource, so-called AFR.



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, 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.

Photo:
Inbound storage of pre-processing facility of Geocycle India.

Pre- and co-processing is not a standalone solution to all waste management needs, but when following the principles and requirements for sound operation as set out in this document, it has its role in an integrated waste management system. AFR use in cement kilns shall respect the waste hierarchy and not interfere with waste reduction efforts. It is beneficial and desirable when it diverts wastes from disposal which cannot be recycled or reused. In this way, pre- and co-processing can make an important and structural contribution to the improvement of waste management in low- and middle-income countries, while at the same time reducing the incidence of open burning, marine littering and disposal in uncontrolled dumpsites.

Pre-processing is a key enabler for co-processing by producing qualified homogeneous AFR from different incoming waste streams and thereby avoiding operational issues during co-processing in the cement production process. It is also the key interface where cement plants interact with local waste management systems. Changes to the waste system related to the introduction of pre- and co-processing should aim to create mutual benefits to local communities, stakeholders in the waste system and the cement producer. To achieve this, pre- and co-processing must be adapted to local conditions (with input of stakeholders) and regularly evaluated for their benefits to the overall situation. These mutual benefits should be clear to all stakeholders and it helps if the changes are measured, documented and monitored.

The use of pre- and co-processing can support waste management, substitute fossil fuels and primary raw materials in cement production, and eliminate harmful substances from the circular economy. This improves resource efficiency and reduces GHG emissions, thereby supporting the 2015 Paris Climate Agreement and the Sustainable Development Goals. Compared with other waste-to-energy technologies such as waste incineration, co-processing has the advantage that it can be incorporated into existing local cement production facilities and does not require major investments in new waste management infrastructure. The high temperature condition in the cement kiln have 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. At the same time, AFR use can decrease waste handling costs and reduce cement production costs. However, there are some basic rules and principles that should be observed, which are summarized by the following guiding principles.

Guiding Principles 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 following guiding principles must be followed to ensure successful implementation. The overarching principle is to be considered as a pre-condition for pre- and co-processing. It is laid out in *Part 1* of this document while *Part 3* specifies corresponding requirements and more detailed information on how to implement these. Here an overview of the guiding principles is given for reference:

Overarching principle

Respect Waste Hierarchy & Circular Economy

- Pre- and co-processing shall respect the waste hierarchy and therefore don't hamper waste reduction, reuse and recycling.
- Pre- and co-processing shall be regarded as an integrated part of modern waste management, as it provides an environmentally sound mineral recycling and energy recovery solution.
- Pre- and co-processing can be regarded as a contribution to the circular economy by reducing the use of fossil fuels and primary raw materials as well as ensuring clean material cycles through elimination of harmful substances.

Implementation principles

Legal & Institutional Framework (I)

- 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 an 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 as well as the set-up of institutional arrangements ensured.

Environment (II)

- Additional emissions and other negative effects on the environment from pre- and co-processing shall be prevented or kept at 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 used as a sink for potentially toxic elements (e.g. heavy metals).

Operation & Quality Control (III)

- 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 ensure continuous control and monitoring of inputs and relevant parameters of their production processes.
- The quality of the cement products (concrete, mortar) remain unchanged.

Health & Safety (IV)	• Companies active in pre- and co-processing shall establish appropriate risk controls to provide healthy and safe working conditions for employees and contractors. • Companies shall have good safety compliance records as well as personnel, processes, and systems committed to protecting health and safety in place.
Inclusivity and Engagement (V)	• Companies active in pre- and co-processing shall engage regularly and communicate transparently with the public, relevant authorities and other stakeholders. • Country-specific and local needs as well as different cultural contexts 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.
Economic & Financial (VI)	• Pre- and Co-processing projects shall be based on a financially sustainable business model, which brings value to all involved stakeholders and local communities. • Financing mechanisms shall be in place to ensure that interventions have financing covered in the medium to long term.
Implementation (VII)	• Monitoring and auditing systems need to be in place to enable successful implementation. • Capacity building and training at all levels is essential.

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 the 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. 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. 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. Management and technical employees must be trained in handling and processing of waste and AFR. 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.

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 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. 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.
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.

Target Groups and Scope

The primary target group for these Guidelines is decision makers in the waste and cement sector. Decision makers in government, non-governmental organizations (NGOs), and civil society are also important parts of the intended audience for these Guidelines, which can support them to understand the principles and minimum requirements for implementing pre- and co-processing in a safe and environmentally sound manner.

The Guidelines aim to raise awareness, provide technical know-how and promote informed dialogue between stakeholders. They can serve as a basis for capacity development and consideration of pre- and co-processing as part of integrated waste management planning.

The scope of the Guidelines is limited to the “front end” processes of pre-and co-processing. It therefore does not address the reuse and recycling of aggregates and concrete nor the use of mineral waste or by-products (e.g. fly ash, synthetic gypsum, granulated blast furnace slag) in cement grinding. While AFR can be used in other industrial processes, this guideline only refers to the use in cement production. A focus is kept on low and middle-income countries where the concept of pre- and co-processing in cement production is not yet widely accepted nor applied.

How to use these Guidelines

The Guidelines are split into three parts to help guide the reader through different areas.

PART 1:
INTRODUCTION

Following the executive summary, the guidance starts by introducing the status of pre- and co-processing worldwide, before going on to explain the challenges of increasing resource consumption and improper waste management. The role that pre- and co-processing can play in helping to address these challenges and to meet climate and SDGs is explained through the perspective of circular economy, as well as how pre- and co-processing relates to other waste management options through the waste hierarchy. It specifies and provides context to the overarching principle.

PART 2:
GENERAL CHARACTERISTICS OF PRE- AND CO-PROCESSING

Part 2 provides the reader with technical aspects of pre- and co-processing, as well as how these interact with and support the local waste management system. It covers the basic characteristics of pre- and co-processing and the cement production process: what types of AFR are there? Where can these be sourced and then fed into the cement production process? What is the climate relevance and where does it fit in the local value chain? Organization of pre- and co-processing in integrated waste management planning is discussed, as well as how important stakeholders can play a role.

PART 3:
REQUIREMENTS FOR ENVIRONMENTALLY SOUND IMPLEMENTATION

The third part represents the most important part of the Guidelines: setting out the requirements for sustainable and environmentally sound pre- and co-processing. This section covers legal and institutional frameworks, environmental emissions control and monitoring, operational procedures to ensure quality control, health and safety, robust financing, communications and engagement with the informal sector. The principles and requirements corresponding to each subject are laid out at the beginning of each section. A closing chapter details next steps for implementation: capacity development and how to apply specific sections of the Guidelines.

Throughout the document selected *case studies* are used to give brief insight into the situation in different countries, while *boxes* highlight key information. No less important are the *Annexes* in *Part 4*, where additional examples, flow charts and reference values are given to support application of the Guidelines.

PART 1

INTRODUCTION

Setting the foundations: Part 1 introduces the status of pre- and co-processing worldwide (1.1), before going on to explain the challenges of increasing resource consumption and improper waste management (1.2). The role that pre- and co-processing can play in helping to address these challenges and to meet climate and sustainable development goals (SDGs) is explained through the perspective of circular economy (1.3), as well as how pre- and co-processing relates to other waste management options through the waste hierarchy (1.4), in line with the overarching principle.

1.1 Pre- and Co-processing Today

There is a large body of experience with co-processing of waste fractions in cement kilns. Fractions of municipal waste, hazardous and non-hazardous industrial waste, commercial waste, agricultural waste & residues, construction & demolition waste and extractive (mining) waste have been successfully pre-processed into waste-derived *Alternative Fuels and Raw Materials* (AFR) and co-processed in cement kilns in Europe, Japan, USA, Canada and Australia since the beginning of the 1980s.

Co-processing has become a well-established and broadly accepted waste management solution in Europe, with some plants managing to substitute up to 100% of conventional fossil fuels with AFs. In Germany, the average thermal energy substitution rate in cement production reached 65% in 2017 (VDZ, 2017a). At the same time, during co-processing the inorganic fraction of AFs (Alternative Fuels) and AR (Alternative Raw Materials) are fully incorporated into the cement, thus replacing natural raw materials, and thereby recycling the mineral fraction of this waste. In recent years, about 17% of raw materials used in the production of cement in Germany consisted of AR, totaling about 8.8 million tons per year (VDZ, 2017a).

Box 1: Definition of Waste:

The European Waste Framework Directive (2008/98/EC) defines waste in article 3 as: “any substance or object, which the holder discards or intends or is, required to discard” (EC, 2008). Waste can be hazardous or non-hazardous, solid, liquid, or pasty (sludge). Any waste material can be defined by its origin (municipality, industry, agriculture, mining etc.); hence a proper categorization should always be established at national level to help creating a common understanding when defining a legal framework.

In 2016 member companies of the *Cement Sustainability Initiative*[1] (CSI), representing about 20% of global cement production, co-processed 21 million tons of AF worldwide (CSI, 2016). *Table 1* shows the development of the thermal energy substitution rates by AF in different regions of the world between 1990 and 2016.

Table 1: Thermal energy substitution rates by Alternative fuel (AF) co-processed in the cement industry in 2016 with limited data coverage in some regions (CSI, 2016).

Region	Thermal energy substituted by AF			
	1990	2000	2010	2016
World	2.0%	5.2%	12.1%	16.7%
Europe	2.7%	9.3%	30.4%	44.2%
North America	3.9%	7.3%	12.7%	15.8%
Latin America	2.1%	4.8%	11.8%	14.2%
Asia Oceania	0.7%	3.6%	4.3%	9.0%
Africa Middle East	0.0%	0.0%	2.1%	6.3%
CIS-Countries	0.0%	0.0%	0.6%	1.8%

1 *The Cement Sustainability Initiative* (CSI) no longer exists in the same form under the World Business Council for Sustainable Development, and was incorporated into the *Global Cement & Concrete Association* (GCCA) on January 1st 2019.

In most cases waste materials can only be used for co-processing after sorting and some form of treatment. This has led to a dynamic development of pre-processing facilities and technology, transforming waste by manual, mechanical, biological or physico-chemical treatment into AFR for the cement manufacturing process and other energy intensive industries. Pre-processing facilities are operated by large waste management companies, many small & medium enterprises and by the cement industry itself.

Box 2: *Alternative Fuels and Raw Materials* (AFR):

AFR refers to selected waste and by-products that can be co-processed in cement production (CSI, 2014). *Alternative Fuels* (AF) have a recoverable energy content (calorific value), which replaces energy needs from a portion of conventional fossil fuels. *Alternative Raw Materials* (AR) contain useful minerals such as calcium, silica, alumina, iron and sulfur, and can replace natural raw materials in clinker production or mineral components in cement production.

Photo:
Refuse Derived Fuel.

Despite more than 30 years of positive experiences with pre- and co-processing in high income countries, acceptance and uptake of AFR in the cement industry has been slow in developing and emerging economies due to limited knowledge of the potential of pre- and co-processing in energy recovery and minerals recycling, lack of legislative and institutional frameworks, as well as economic and financial uncertainties. Resistance to incineration of waste and the related concerns of the public, civil society regarding potential environmental and health impacts may also play a role. More recently, competition for materials in the informal and formal waste value chains have raised concerns of fairness, equity, and inclusivity, and these issues represent a new dimension in these Guidelines.

Based on the first version of these Guidelines, the CSI elaborated in 2014 guidelines for Co-processing Fuels and Raw Materials in Cement Manufacturing (CSI, 2014), updated in 2018 (GCCA, 2018). In addition, since 2011 the Basel Convention has recognized co-processing as an environmentally sound waste management solution for hazardous wastes and other waste (UNEP, 2011). Recognition is an important first step, but developing pre- and co-processing as a safe and environmentally sustainable waste management option also requires investments in technology, regulatory knowledge and rigorous permitting and quality assurance procedures. Reaching the status of an effective waste management solution in Europe has occurred gradually over 15 – 20 years, and has been supported by stringent legislation to monitor quality and emissions. Moreover, the developments in pre- and co-processing are also closely linked to changes in the legal, institutional and financial framework for waste management, such as taxation or bans for landfilling.

In 2018 the *International Energy Agency* (IEA) and CSI published the second edition of their climate technology roadmap for the cement sector, in which co-processing of AFR plays a major role in meeting climate reduction goals by 2050 (IEA/CSI, 2018). Governments in emerging countries such as India, Egypt, Brazil and Indonesia have also established policies and roadmaps encouraging corporate and public decision makers to stimulate higher rates of co-processing as one way to meet their waste management, climate and sustainability goals (WBCSD/IEA, 2012), (Vanderborght, et al., 2016), (SNIC, 2019). In some other low- and middle-income countries, governments together with cement producers are only at the stage of considering first steps to include pre- and co-processing into their policies and roadmaps. Better and updated guidance on pre- and co-processing is therefore needed, and will likely be of strategic importance for the cement industry in its goals to formulate a sustainable, socially responsible approach to improving waste management in rapidly growing cities of low and middle income countries.

1.2 The Resource and Waste Challenge

Population growth, economic growth, rapid urbanization, increased prosperity and modern lifestyles go hand in hand with increased resource consumption. Global resource use has quadrupled in the last 40 years and shows no signs of slowing down (IRP, 2017). This depletion of natural resources is a cause for concern, as the limits of multiple planetary boundaries necessary to maintain vital support systems for climate, agriculture and marine life are already exceeded (Rockström, et al., 2009).

The construction sector is responsible for approximately half of all resource use (De Wit et al., 2018). As the primary construction material used in meeting the building and infrastructure needs of modern life, concrete is the most consumed resource worldwide, after water. The key ingredient which gives concrete its strength is cement, representing typically about 10 – 15% of the mass of concrete, binding the aggregate raw materials such as sand, rock and gravel together.

Annual cement production, mainly driven by growing demand in expanding urban areas of low and middle-income countries, has increased dramatically in the last 15 years, with average increases of 5% per year. Global cement production has gone from 1.8 Gt in 2002 to 4.1 Gt in 2017 (USGS, 2013). During this period China's cement production has increased fourfold, so that China now accounts for more than half of global cement production. Global demand and production is forecast to continue its growth, with the IEA-CSI technology roadmap predicting an increase of a further 12 – 23% by 2050, led by growth in developing countries (IEA/CSI, 2018).

Producing cement is an energy intensive process. Production of clinker (the main component of cement) requires limestone and other ingredients to be heated to temperatures of 1,450°C, enabling the calcination and clinkerization reactions. The high temperatures require combustion of substantial quantities of fuels, which traditionally consisted of conventional fossil fuels such as natural gas, coal or petcoke. As a result, cement production contributes roughly 7% of global anthropogenic *greenhouse gas* (GHG) emissions, 60 – 70% from the calcination of the raw materials and 30 – 40% from the combustion of fuels. As a major resource user and generator of CO_2 emissions, the cement industry has a key role to play in efforts to decouple resource use and carbon emissions from economic growth.

At the same time the Worldbank estimates that global *Municipal Solid Waste* (MSW) generation in cities will increase from 2,001 Mt in 2016 to 3,400 Mt in 2050 (Kaza et al., 2018), with the highest increases in the rapidly growing cities of low and middle income economies. In these countries waste management remains a major challenge as an estimated two billion people worldwide do not have access to solid waste collection, and at least 3 billion people worldwide still lack access to controlled waste treatment and disposal facilities (UNEP, 2015).

When not collected, waste is in many cases dumped and burned openly near the source causing proliferation of infectious diseases and respiratory problems. The waste often leaks into waterways causing blockages or ultimately polluting the marine environment. Efforts to increase collection rates are a precondition to increase the amount of waste treated in a safe and environmentally sound manner. However, in many cases the waste quantities collected do not reach recycling, recovery or controlled disposal facilities, but are sent to uncontrolled dumpsites instead.

Photos:
Olusosun dumpsite
Lagos, Nigeria.

Construction site
in Dubai.

Inadequate waste management practices are associated with pollution of air, water, and soil, negative ecosystem impacts, and the deterioration of living conditions and human health. Toxic substances and persistent chemical compounds escape into the environment, spread through air and water over large areas, and finally enter the food chain affecting human and animal health. According to the *International Panel on Climate Change* (IPCC), the waste sector accounts for around 3% of global anthropogenic GHG emissions, of which approx. 0.6 Gt CO_2eq arise from landfilling, 0.75 Gt CO_2 eq from wastewater treatment and the rest from incineration and other waste treatment (EPA, 2014).

However, the above-mentioned estimate neglects major emissions sources such as the open burning of waste, which emits black carbon (soot), short lived climate pollutants and stable toxic compounds. Studies estimate that open burning alone could be responsible for up to 5% of global anthropogenic GHG emissions (EPA, 2014). Furthermore, the potential GHG reductions from improvements in the waste management sector are underestimated, as they are often attributed to reductions in other sectors. For example biogas from anaerobic digestion of food waste is considered as renewable energy production, while co-processing of biogenic waste fractions is considered as CO_2 reduction in cement production. The Global Waste Management Outlook uses a lifecycle approach to arrive at an estimate that 10 – 15% of global anthropogenic GHG emissions could be avoided through improved waste management practices (UNEP/ISWA, 2015).

To address and change poor waste management practices, stakeholders from different sectors are needed, and in this context pre- and co-processing can play an important role. When applied in line with the requirements set out in these Guidelines, there is considerable evidence that the combined strategy of pre-processing of non-recyclable fractions of residual waste into AFR and subsequent co-processing in cement plants provides a safe, environmentally sound and cost-effective waste management solution for a wide range of wastes. The most harmful substances are destroyed by the high operating temperatures, providing an environmental win-win situation: less waste to landfill, lower percentages of fossil fuel, lower CO_2 emissions in cement production, and reduction of non-recyclable fractions of plastics that could otherwise enter the marine environment. The mineral fraction of the waste is incorporated into the cement clinker, meaning that there are no residual ash or effluent fractions, in contrast to other waste-to-energy (WtE) technologies such as mass incineration, gasification or pyrolysis. An additional advantage of co-processing is that operational cement plants are already present in virtually every country: co-processing is therefore a strategy to upgrade a waste management system without large investments into new infrastructure for waste disposal.

1.3 Goals of the International Sustainability Agenda

Humanity is in urgent need of circular resource utilisation models where extracted resources circulate through many life cycles and are renewed as industrial inputs, rather than becoming waste at the end of their first useful life as product or package. There is a growing consensus that drastic increases in global resource use are symptoms of a linear industrial economic model which maximizes extraction, production, sales, consumption and disposal. The result is a rapid global growth in waste generation.

In September 2015, the international community ratified the United Nations 2030 Agenda for Sustainable Development. The 2030 Agenda comprises 17 *Sustainable Development Goals* (SDGs) to guide global policy and funding for the next 15 years. The SDGs aim at achieving decent living conditions for a growing world population without passing crucial environmental limits.

Figure 1: SDGs linked to resource efficiency and waste management.

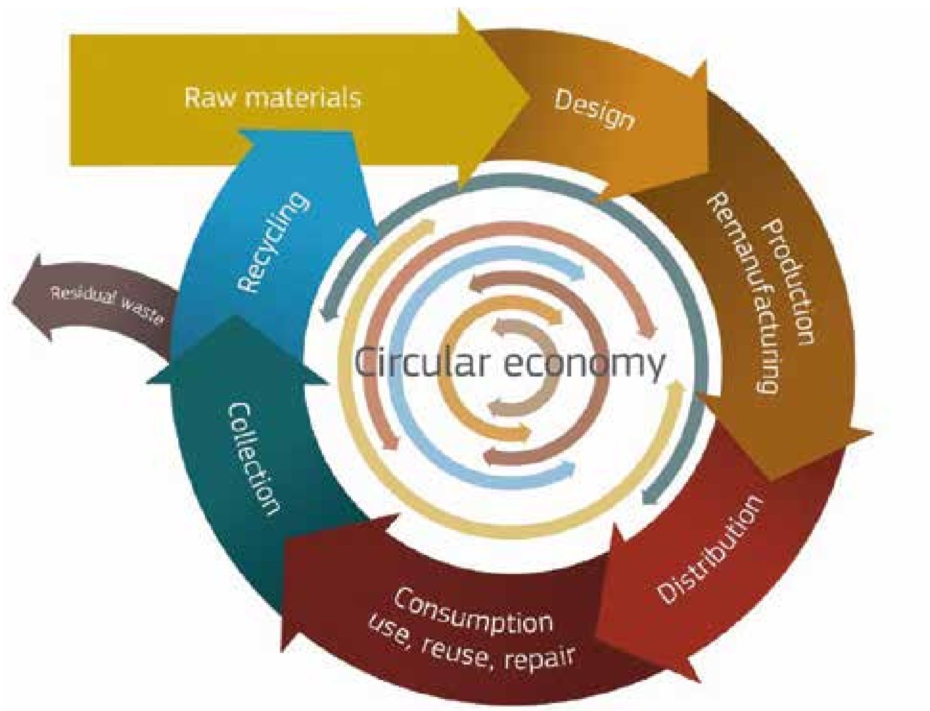
Among the 17 SDGs, SDG 9 (Inclusive and Sustainable Industrialization), SDG 11 (Sustainable Cities and Communities), SDG 12 (Sustainable Consumption and Production) and SDG 13 (Climate Action) are of relevance for decision-making around pre- and co-processing, as they have targets for increased resource efficiency, better waste management practices, and reducing the release of chemicals and pollutants to air, water and soil. The potential benefits of meeting the sustainability goals are huge: the *International Resource Panel* (IRP) estimates that a shift to resource efficient pathways could reduce 28% of natural resource use, and as much as 72% of global emissions (IRP, 2017).

Meeting the SDGs is strongly linked to reducing poverty, creating decent livelihoods, and reducing impacts from climate change – one of the biggest challenges humankind faces in the years to come. In this regard, the international community also endorsed the Paris Climate Agreement in December 2015 and committed to limiting global warming within this century to a maximum of 2 degrees Celsius above pre-industrial levels. Reaching the climate targets and SDGs requires a change from “business as usual” in industrial production, and different modes of international cooperation.

Meeting SDG 11 on sustainable cities, which focuses on improved waste management until 2030, as well as SDG 13 on climate action is a challenging task for the waste sector and cement industry. To address this challenge, IEA-CSI has developed a technology roadmap for meeting the 2 degree Celsius target by 2050, which would require reductions in annual direct emissions from cement production of 24% compared to current levels. Cumulative CO_2 savings to 2050 are expected to come from energy efficiency measures (3%), substitution of fossil fuels with alternative fuels (12%, the subject of this guideline), reduction of clinker ratio in cement (37%), and future carbon capture and innovative technologies (48%) (IEA/CSI, 2018). For more information on how fossil fuel substitution by AF affects the CO_2 balance of cement production, *see section 2.4*.

SDG 12 is based on the concept of a circular economy: a new model for a greener economy, which aims to decouple economic growth and human well-being from ever-increasing natural resource consumption and associated environmental impacts. The circular economy represents a systemic change away from the ‘take, make, dispose’ model, towards an economy where products, components and materials are circulated for as long as possible at the highest utility at all times.

Figure 2: Concept of the circular economy (European Commission, 2014).



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. Major efforts are required in the transition to a circular economy, as currently only 9.1% of materials worldwide are cycled in the global economy (De Wit et al., 2018). In waste management the priority lies first in improving collection rates of all wastes and following the waste hierarchy (*see the following chapter* for more details). Pre- and co-processing – classified as mineral recycling and energy recovery – represent a lower priority solution than material re-use or recycling in terms of the waste management hierarchy, and this is also reflected in the Guiding Principles set out in the executive summary. These Guidelines take the position that despite its place in the hierarchy, co-processing can make an important and structural contribution to the improvement of waste management in low- and middle-income countries, by partially meeting the pressing need for controlled disposal and energy recovery and reducing the incidence of open burning, marine littering and disposal in uncontrolled dumpsites. Specifically, pre- and co-processing can make important contributions to CO_2 reduction and the circular economy transition through:

- a 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
- best use of residual waste which reached its end-of-life status and can't be recycled anymore
- conservation of primary resources (raw materials and fuels) by replacing them with secondary resources
- energy recovery from waste materials for which recycling facilities are not yet available or recycling technologies are financially not feasible.

Box 3: Marine Litter – a new threat to aquatic ecosystems

Marine litter is another emerging global issue recognized internationally in Sustainable Development Goal 14.1 "Prevent and significantly reduce Marine Pollution of all kinds, in particular from land-based activities".

Plastics and microplastics have become globally ubiquitous in oceans and freshwater environments, raising concerns regarding their impacts on health and biodiversity. About 60-90% of marine litter consists of plastics (UNEP, 2016), with the vast majority originating from land-based sources, entering into the marine environment from human settlements as a result of shortcomings in municipal waste collection and treatment systems. It is estimated that worldwide around 4.8 to 12.7 Mt of plastic waste enters the sea only from land sources and populations living within 50 km from the coast (Jambeck, et al., 2015), whilst rivers may contribute an additional 1.2 to 2.4 Mt per year (CIWM, 2016). Thirty-eight of the world's fifty largest uncontrolled dumpsites are in coastal areas, many of them spilling waste directly into the sea (ISWA, 2016). Numerous initiatives have been launched to raise awareness and commitments to combat marine litter. Local actions such as extending municipal solid waste collection to all in developing countries, improving recycling rates and eliminating uncontrolled disposal, could cut the quantities of plastics entering the oceans by half (CIWM, 2018). As moderate-cost options, pre- and co-processing of non-recyclable plastic waste can help upgrade waste management systems and reduce uncontrolled disposal. This in turn has the potential to reduce or eliminate land-based emissions that end up as marine litter.

Photo: Marine litter on beach.

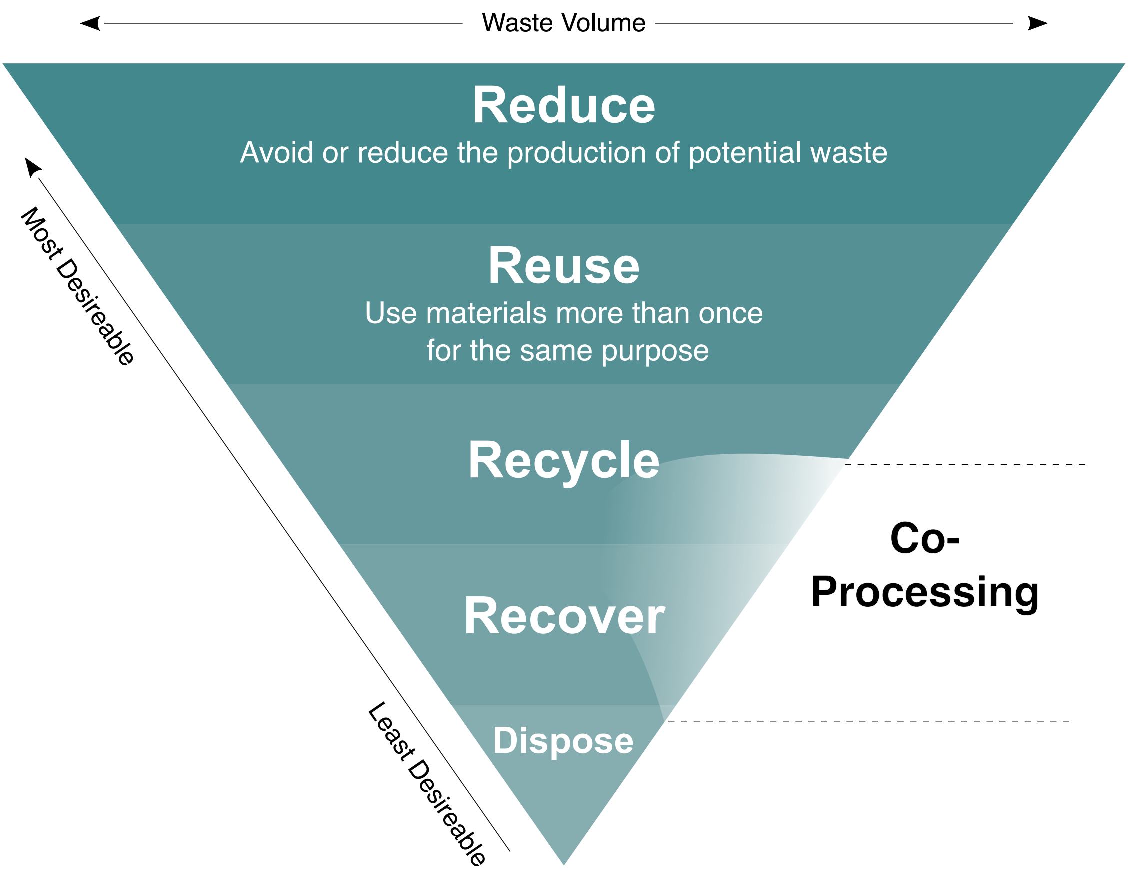
1.4 The Waste Hierarchy

The waste hierarchy is a broadly accepted global framework for policymakers on designing waste management systems, considering resource management, environmental, and financial considerations.

In the context of these Guidelines the waste hierarchy serves the purpose of illustrating the relevance of pre- and co-processing in comparison with other waste management options. The waste hierarchy is defined largely as follows, in accordance with the European Waste Framework Directive (EC, 2008):

- *Prevention or reduction* of waste is the most desired solution, meaning that measures are taken at the design, production or use stage before a substance, material or product becomes waste.
- *Reuse* refers to any operation by which products or components are used again for the same purpose for which they were originally conceived.
- *Recycling* means any operation through which wastes are reprocessed into products, materials or substances whether for the original (closed-loop) or other (open-loop) purposes. Pre-processing can improve collection and sorting of materials for recycling, while co-processing recycles the mineral content (i.e. Ca, Al, Fe, Si) of waste for the purpose of cement production.
- *Recovery* means any operation whose principal aim is to use waste as a useful resource by substituting other materials, including fuels. Co-processing recovers the organic content of the waste in the cement kiln as thermal energy, substituting conventional fuels.
- *Disposal* is the least desired solution. Controlled disposal (sanitary landfill, incineration with no or limited energy recovery) should only be used for waste which cannot be managed by any of the above waste management options. Uncontrolled disposal (dumping, open burning) poses a major threat to the environment and human health and should be prevented. For some hazardous waste (e.g. pesticides, PCB), where recycling and recovery is not possible, co-processing is also an environmentally and financially sound disposal option.

Figure 3: Waste management hierarchy. Co-processing overlaps with the levels recycle, (energy-) recovery and for selected waste with dispose.



By applying the waste hierarchy it becomes obvious that materials which can be recycled in a closed-loop (metals, paper, glass, certain plastic types) should not be accepted for pre- and co-processing. In this sense pre- and co-processing is complementary and not in competition with closed-loop recycling.

The definition of "closed-loop recycling" is not the same in all policy systems, but in general it means that the materials to be recycled ultimately end up in a production process and manufacturing system that manufactures materials or products similar to those that were originally produced, used, and disposed. In general, materials suitable for closed-loop recycling processes are:

- separated for recycling because they are either designated by laws, public policies or targets, or on the other hand actively sought, purchased and processed by potential commercial users based on their quality and intrinsic value
- marketable to the value chain within the region
- captured before they are mixed with organic and other non-recyclable waste materials, or in some cases extracted by hand by informal recyclers from mixed waste streams
- separately collected or processed into secondary resources
- traded to industry for industrial inputs, or because they will be traded further
- used as inputs to manufacturing.

Whether recycling is a real option in a specific place, and at a specific time, is highly context-sensitive.

Box 4: Dynamic relation between recycling and co-processing

Recyclability is not just a technical criterion, but an industrial and economic one as well. There are many situations where closed-loop recycling is not attractive, and even some cases when the local value chains are too weak to absorb all recyclable materials. Sometimes this is because the lower levels of the value chain are absent or too far away, public entities lack knowledge of marketing or infrastructure to ensure correct separation and handling of materials or because of market and price fluctuations in the recycling value chain. Further technical hurdles to recycling of MSW are small formats (e.g. sachets), multi-material packaging, contamination with organics (e.g. food in takeaway packaging), additives and black plastics that usually cannot be detected by recycling plant sensors.

In these situations, inclusion of materials in Alternative Fuel and Raw material – on a dynamic basis – might be better than disposal or long-term storage. Thus, it is very helpful that the waste authorities, the operators of pre-processing facilities and cement companies engaged in co-processing have a consultation process that allows them to jointly make decisions, and direct materials which are not easily stored and cannot be currently re-used or recycled to pre- and co-processing. This is an example of dynamic decision-making in real time, and it immensely increases the value of pre- and co-processing to the whole waste management system. It also conforms with the principle of developing shared benefits to all stakeholders in the local value chain. For this reason, it is important to design or adapt pre-processing lines and facilities so that they can treat recyclables differently at different times. This ensures that recycling and co-processing can maintain a dynamic relationship and do not necessarily compete against each other.

There is a great deal of dynamism in national enabling environments affecting waste systems, and the globalized institutional and economic landscape of recycling. Further optimization of closed-loop recycling and envisaged new legal requirements based on the concept of circular economy will result in more materials being diverted to recycling with time. However, due to improved collection rates and complete bans on uncontrolled waste dumping and open burning, it can be expected that absolute waste quantities available for co-processing will actually increase. Pre-processing is increasingly necessary in modern waste systems, increasing the long-term potential for flexible co-processing in many markets. Pre- and co-processing will thus remain a technically feasible, economically viable and environmentally sound technology in the years to come.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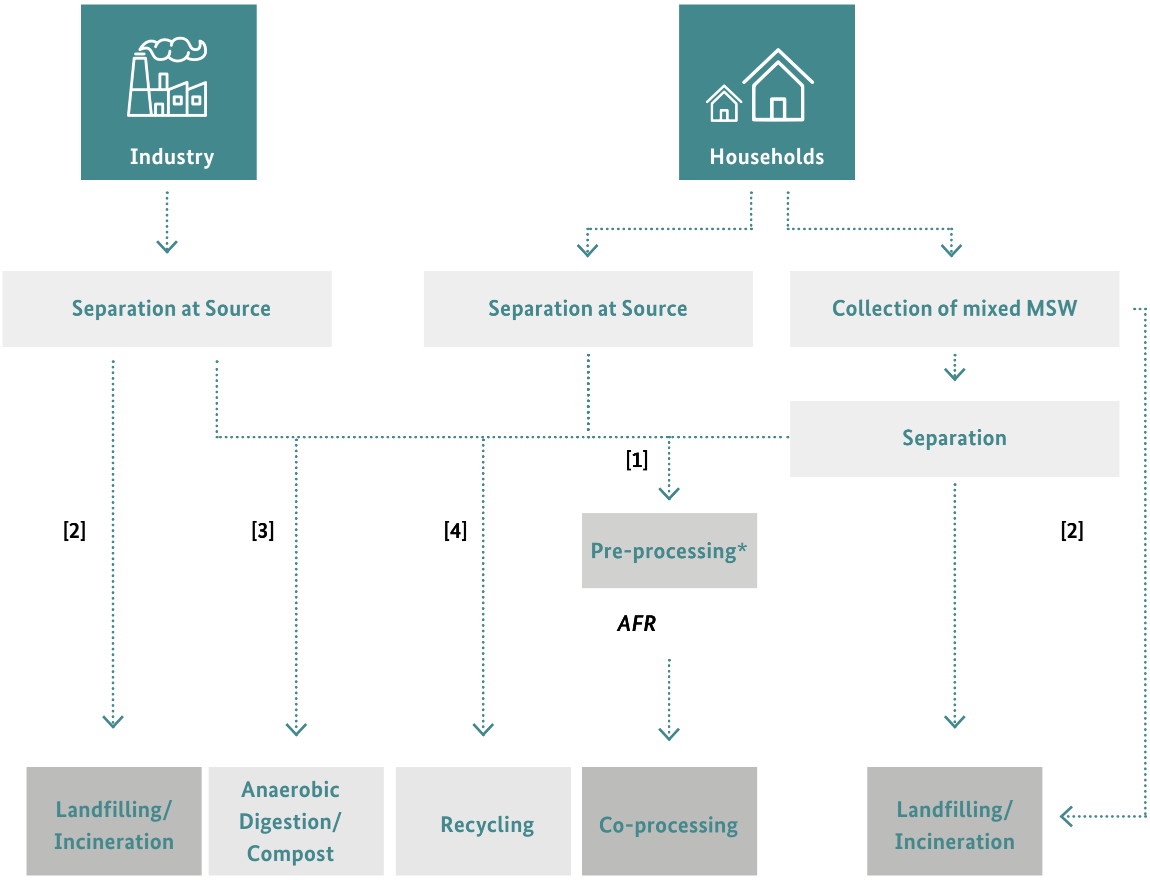
PART 2

GENERAL CHARACTERISTICS OF PRE- AND CO-PROCESSING

Reinforcing your knowledge: Part 2 looks at the technical characteristics behind both pre- and co-processing, and where these fit in the local value chain. The chapter starts by discussing different waste types and their suitability for co-processing (2.1), it then looks at different pre-processing techniques (2.2). Following this, an overview of co-processing in the cement production process is given (2.3) and why this is particularly suitable for treating AFR, as well as how this affects the climate relevant emissions (2.4). Finally, considerations are given on how pre- and co-processing can be incorporated into integrated waste management planning (2.5) and organized in the existing waste management system (2.6).

2.1 Wastes Suitable for Pre- and Co-processing

Figure 4: 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

Waste fractions suitable for closed-loop recycling, such as cardboard, hard plastic, glass or metal, are in most developed countries separated at source or sorting stations after waste collection. In emerging and developing countries, the separation of recyclables is often done by the *informal recycling sector* (IRS) during collection, at transfer stations or on the landfill itself.

Only very few waste types (e.g. whole tires) can go directly to the cement plant for co-processing without further treatment. All other waste suitable for co-processing are first transferred to dedicated pre-processing facilities for the production of AFs or raw materials. The selection of which waste and AFR is suitable for pre- and co-processing needs to follow a comprehensive risk-based qualification and acceptance procedure to ensure safe and environmentally sound pre- and co-processing.

The basic concept behind pre- and co-processing as part of an integrated waste management system are illustrated in *Figure 5*.

Figure 5: Integration of pre- and co-processing in a MSW management concept.

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 from natural resource, while the organic content of the waste is recovered as thermal energy, substituting conventional fuels.

Photos: Mechanical screen in pre-processing platform.

Rubber waste after shredding.

2.1.1 Waste and AFR Selection

A wide variety of residual waste materials have been successfully pre-processed into AFR for co-processing in cement kilns. Key target streams include fractions of MSW, hazardous and non-hazardous industrial waste, commercial waste, as well as agricultural residues and construction & demolition waste. *Figure 6* shows the main waste types suitable for co-processing, identifies their sources, and provides some rough estimates about global generation and their availability.

Figure 6: Waste types relevant for pre- and co-processing.

	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

In order to ensure safe and environmentally sound pre- and co-processing it is necessary to specify selection criteria and to restrict the use of certain wastes. The waste selection and acceptance for pre-processing facilities should in general be dictated by the following criteria:

PRE-PROCESSING

- Avoid waste that is unsuitable for pre- and co-processing
- Ensure most favorable treatment according to the waste hierarchy by cooperating with the local value chain
- Fulfill any legal, environmental, operational and health & safety (H&S) requirements of the pre-processing facility
- Optimize the net financial and economic costs of waste management
- Ensure the AFR acceptance criteria of the cement plant can be met
- Design the pre-processing facility to enable dynamic choices about materials to be selected and to respond to market and other conditions.

Similarly, the AFR selection and acceptance for co-processing at the cement plant can be charaterized as follows (*see also chapter 3.3.4 Quality Control and Assurance*):

CO-PROCESSING

- Fulfill all legal, environmental, operational and H&S requirements of the cement plant
- Maintain or improve all product quality standards for clinker, cement and concrete
- Maintain affordability in relation to the costs of cement production.

The waste selection process described above should be based on a comprehensive environmental and quality management plan for each pre- and co-processing site, including:

- Waste and AFR pre-acceptance (source qualification)
- Waste and AFR acceptance
- AFR quality and product quality control
- Emission monitoring and reporting.

Annex 14 illustrates waste and AFR quality control schemes for a pre-processing platform and cement plant. *The table below* summarizes the most common waste and AFR properties and their potential impacts on environmental, operational, H&S and product quality requirements.

Table 2: An Overview of potential impacts of most common waste and AFR properties.

Properties	Environment	Health & Safety	Operation	Product Quality
Calorific value			X	
Moisture			X	
Ash				X
Chlorine, sulfur			X	X
Heavy metals	X	X		X
Organics	X	X		
Mineralogy			X	X
Granulometry			X	
Flash point		X		

Waste and AFR quality data and emissions data not only form the basis for ensuring compliance to authorities, but also for discussions with external stakeholders to address local concerns that pre-processing facilities or cement plants could potentially be misused for uncontrolled disposal of wastes.

In some countries, regulators have defined certain acceptance criteria for wastes or AFR in the form of pollutant limit values (*see Annex 6*). No generally agreed limit values exist, as different criteria are applied, depending on the local situation.

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.

Such limit values should be defined, prepared, and regularly reviewed by national or local authorities in cooperation with the waste management sector and cement associations. The aim is to define limit values appropriate for the local circumstances and requirements.

Photo:
AFR Quality Control.

2.1.2 Commonly Restricted Waste

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 (see explanations for this in *Annex 7*):

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

Individual pre-processing facilities and cement plants may also exclude other materials depending on the available treatment process and equipment, local raw material and fuel chemistry, the type of cement production process, the availability of laboratory equipment, available equipment for AFR handling and feeding, and site-specific health, safety and environmental issues.

2.2 Pre-processing – From Waste to Resource

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, to transform them into a homogeneous AFR that complies with the environmental and operational requirements of the cement plant.

Pre-processing facilities involve different unit operations such as separation/sorting, mixing/blending, size reduction (shredding or crushing) and drying. Different processes for waste derived fuel production are described comprehensively in the EU *best reference* (BREF) document for the Waste Treatment Industries (BREF, 2017).

Solid wastes are typically pre-processed by mechanical or mechanical-biological treatment to produce solid AFs (e.g *solid recovered fuel* (SRF), *refuse derived fuel* (RDF)). In case the waste contains little or no biodegradable materials, the pre-processing facility enhances the feed only by mechanical treatment, mainly through size reduction and removal of non-combustible inert materials (stones, glass, metals, etc.). *Figure 7 below* illustrates a mechanical treatment process with primary shredder, gravity separator (windshifter) and secondary shredder.

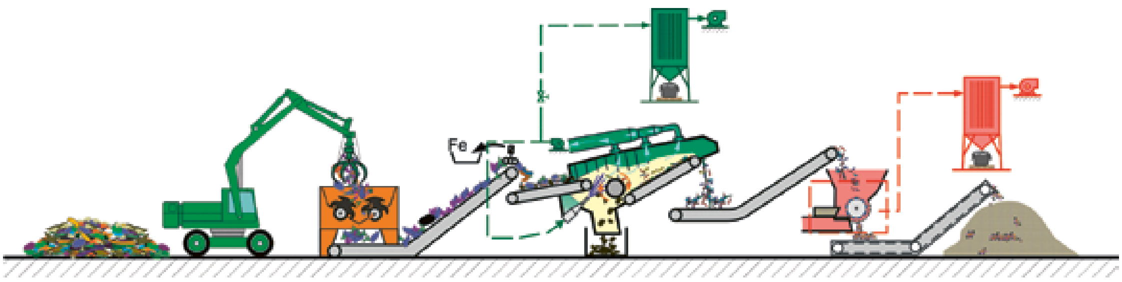


Figure 7: Mechanical treatment (2-stage shredding) for solid alternative fuel production (Geocycle).

In cases where the solid waste also contains significant amounts of biodegradable materials, a combined *mechanical-biological treatment* (MBT) may be used. The biological treatment consists of a partial exothermic aerobic degradation of the organic waste fraction. The biological processes used for solid AF production are usually based on forced aeration and lead to a moisture reduction (biodrying) as well as an odor reduction through biological stabilization (Velis et al., 2009). In some cases, solid AFR is also dried thermally to further increase its calorific value. The thermal drying processes preferably use excess heat from the cement kiln or solar energy as a heat source.

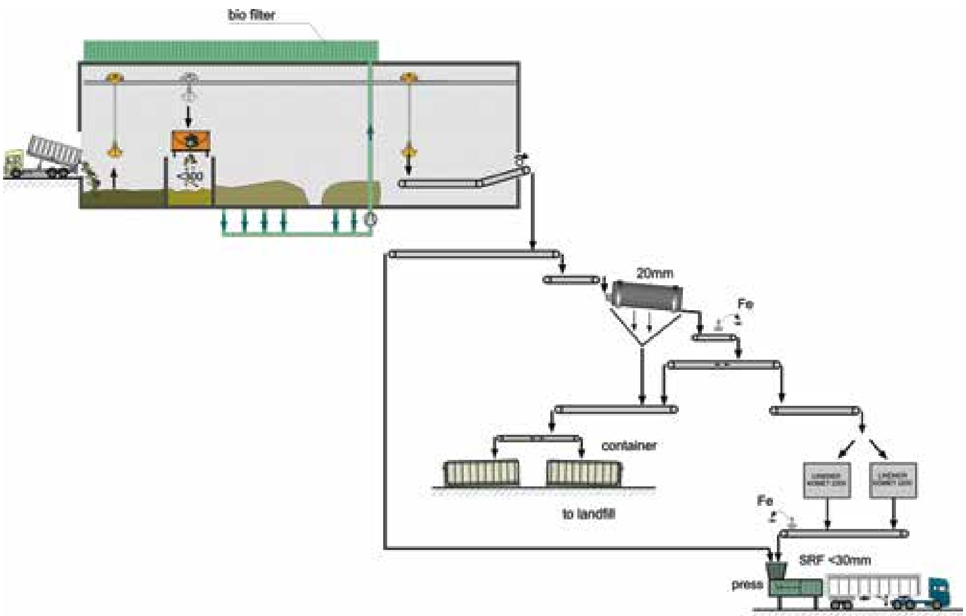
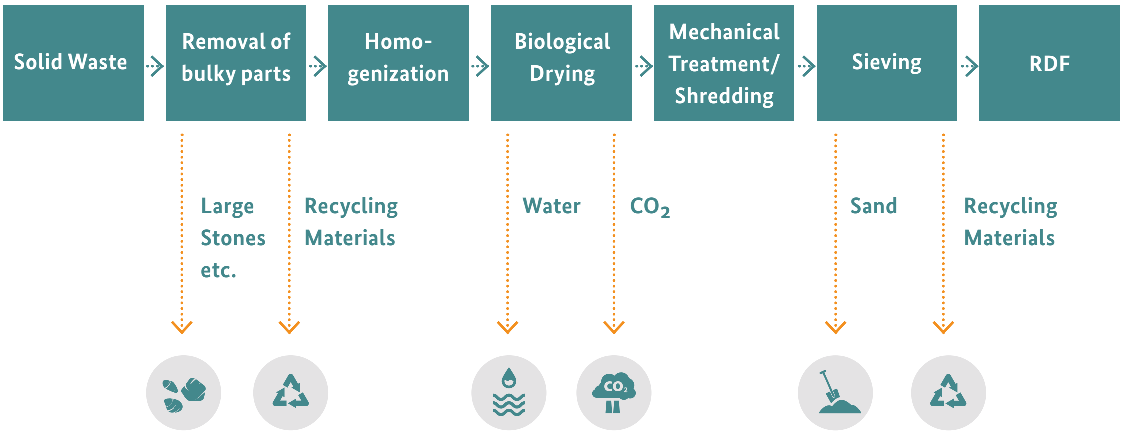


Figure 8: Mechanical-Biological treatment (MBT) for solid AF production (Geocycle).

Figure 9: Generic process flow of MBT for the generation of RDF (GIZ, 2017).



Case study 1: MSW Pre- & Co-processing at Huaxin, China

Photo: Huaxin Eco MSW pre-processing facility Wuhan, Hubei province, China.

Like in many other low and middle income countries, in China MSW is not separated at source, hence the organics and water content is very high: especially in summer time it can be as high as 80%. At the same time the inert fraction can be as high as 40% in rural areas (e.g. ashes from household coal firings). These properties make co-processing of unsorted MSW in cement kilns impossible.

Huaxin proposed to develop and build a pre-processing facility focusing on MSW drying and separation of recyclables and inerts to produce RDF suitable for cement kilns. The main purpose of pre-processing is a reduction of the moisture content to about 35% and to increase the net calorific value to 8 – 10 GJ/t by biological treatment. In addition a RDF feed system has been added to the existing cement kilns to enable co-processing of RDF. At the cement plant, RDF reception and storage, dosing and feeding system, as well as fire detection, alarm and firefighting systems have been constructed. RDF co-processing rates of 700 t/day have been reached at the precalciner for a cement kiln with 5,000 t/day clinker capacity, corresponding to a thermal substitution rate of 54%.

The biggest challenge was to find the optimum operation parameters for the fermentation, leachate treatment and bio-filter for different compositions of MSW during different seasons. One of the main conclusions is that no standard solution exists for MSW pre-processing. The design and operating parameters need to be optimized on a case by case basis, depending on the local quality and seasonality of the MSW. It is also crucial to find a suitable breakeven point between the investment and operation cost for pre-processing and co-processing benefits to optimize the value generation of the whole process. Before developing the conceptual design for such a project, it is therefore essential to get a good understanding of the waste quality, ideally based on a full year waste characterization campaign.

Liquid, paste-like wastes or sludges can be pre-processed just by mechanical treatment, blending (homogenization) and removal of oversized solids, or physico-chemical treatment. The mechanical treatment produces liquid or paste-like AFs that require dedicated liquid or sludge feeding installations for co-processing at the cement plant. The physico-chemical treatment, mainly applied for hazardous wastes, produces instead a solid alternative fuel by mixing the liquid and paste waste with an adsorbent such as sawdust until all free liquid is adsorbed.

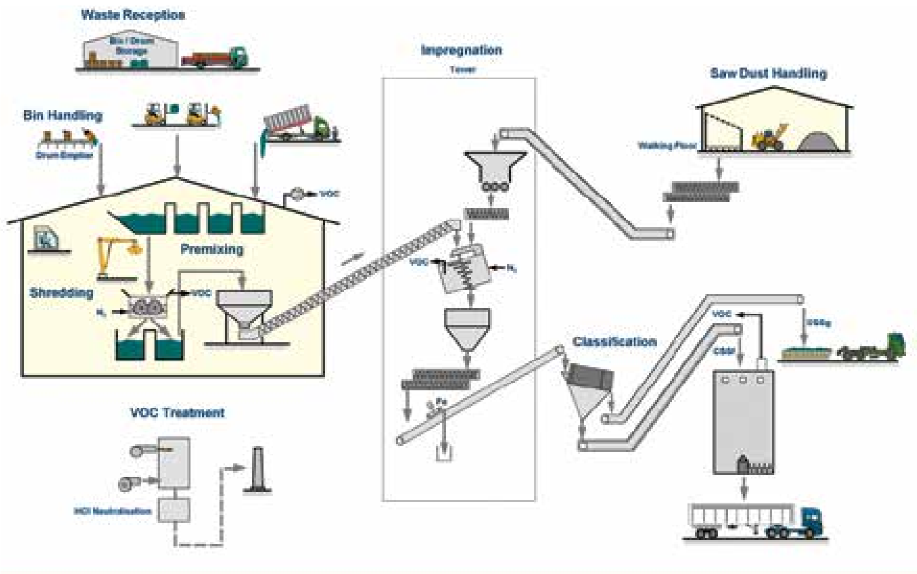


Figure 10: Physico-chemical treatment for solid AF production (Geocycle).

Case study 2: Oil Sludge to Energy at Fujairah (Geocycle, United Arab Emirates)

Photo: Oil sludge pre-processing facility at Fujairah, UAE.

Oil sludge is a waste generated in large volumes in oil rich countries that is difficult to treat. One of the key challenges in turning it into AFR is the highly heterogeneous composition of the waste material (contaminants, variable viscosity, chlorine, ash). The oil sludge therefore needs to be pre-processed by screening and blending such that the sludge delivered to the cement plant meets all required quality specifications.

Oil sludge received at the Geocycle pre-processing facility is stored as per its physical state, liquid sludge in pits and dry sludge on concrete floor yards. Samples are drawn from each delivery to test for quality compliance as per waste pre-qualification and acceptance criteria. The contaminants, mainly plastic, wood, stones, and metal pieces, are segregated by screening the oil sludge using a screening bucket fitted to an excavator. Dry and liquid sludge from different sources is then blended according to a recipe set by the quality control staff to achieve sufficient material fluidity and the right quality specification as defined by the cement plant. The pre-mixed sludge is then again screened to ensure good homogeneity before delivery to the cement plant.

So far more than 100,000 t of sludge have been successfully pre- and co-processed over a period of 7 years of operation. An average heat value of 15 GJ/t is recovered from the sludge. The experience shows that the calorific value can vary significantly depending on the source and type of oil sludge, while the financial profitability is dependent on the fluctuating conventional fuel (coal) market price. To ensure reliability it was useful to secure large volumes and long term contracts. Multiple contracts need to be established to reduce the risk of single source dependence.

AR are primarily derived from large volume industrial waste mono-streams that do not require specific pre-processing. Mechanical treatment, shown in *Figure 11*, is usually restricted to cases where AR is produced from several smaller waste streams with relatively high variability in chemical composition or a high incidence of foreign bodies.

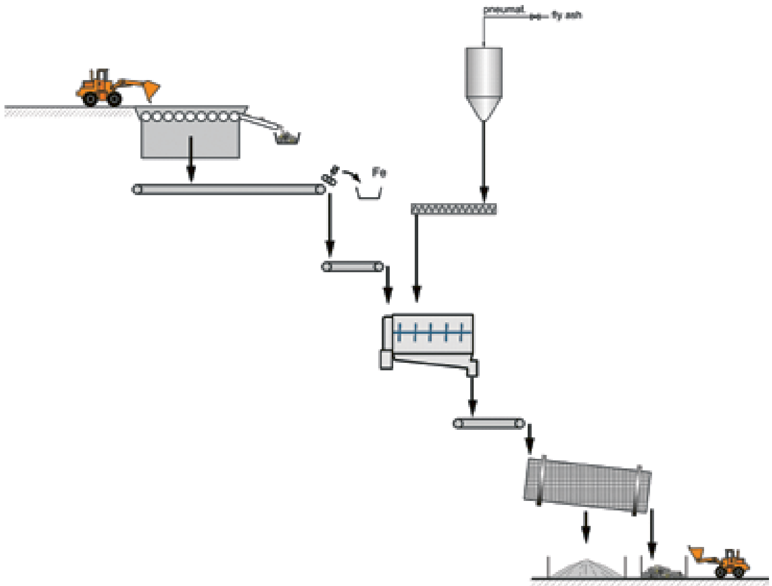


Figure 11: Mechanical treatment for AR production (Geocycle).

Case Study 3: Using Construction and Demolition Waste (CDW) as alternative fuel and raw material at Retznei, Austria.

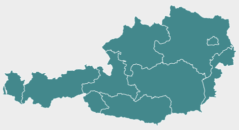


Photo: Recycling Center Retznei, Austria.

The LafargeHolcim cement plant in Retznei already substitutes high amounts of thermal energy with alternative fuels. With the creation of the *Recycling Center Retznei* (RCR), it now also sets a good example in recycling construction and demolition waste. Built in the quarry of the cement plant in Retznei, the operation is made possible by a cooperation between Geocycle and a local partner that provides the knowledge and expertise in construction and demolition waste management.

When a CDW stream arrives at the recycling center, 35% is co-processed as alternative raw material in the production process at the cement plant. Another 35% is treated and sold as alternative raw materials to private customers and construction companies to use in drainage systems. As a result, every year 100,000 t of CDW are processed for reuse. Today, 12% of the raw materials used to produce cement in Retznei come from recycled waste. This approach ensures:

An optimal use of the waste thanks to co-processing that prevents waste from going to landfill.

- An increased resource efficiency by preventing the use of natural resources: the plant substitutes 85,000 t of natural raw material every year.
- A contribution to reducing greenhouse gas emissions by using local waste instead of extracting and transporting natural resources and avoiding decarbonisation of limestone, the traditional natural resource used to produce cement.
- Local activity by creating three new direct jobs and several indirect positions.

2.3 Co-processing

2.3.1 Cement Manufacturing and Co-processing

Cement production is a very material and energy-intensive process. After the natural raw materials are mined, they undergo various steps of mechanical treatment such as crushing, grinding, and homogenization to produce in the raw mill the so-called raw meal. The raw meal enters the cement kiln system where the thermal processes (drying, preheating and cooling) and chemical reactions (calcination, clinkerization) take place to produce the intermediate product clinker. Finally the clinker is milled together with gypsum and other constituents to produce cement.

Producing one ton of clinker requires on average 1.5 – 1.6 tons of raw materials. Most of the weight loss occurs from the calcination, the reaction of calcium carbonate ($CaCO_3$) to lime (CaO), that takes place once the raw meal is heated up to 800 – 900°C. As the temperature in the rotary kiln is increased up to 1,450°C, the clinkerization process takes place as lime, silica, alumina, and iron react together and combine to form clinker. Naturally occurring calcareous deposits such as limestone, marl, or chalk are the source for the calcium carbonate. The main correctives (silica, iron and alumina) usually come from natural ores and minerals, such as sand, shale, clay and iron ore. However, waste-derived ARs can be used to replace these natural correctives.

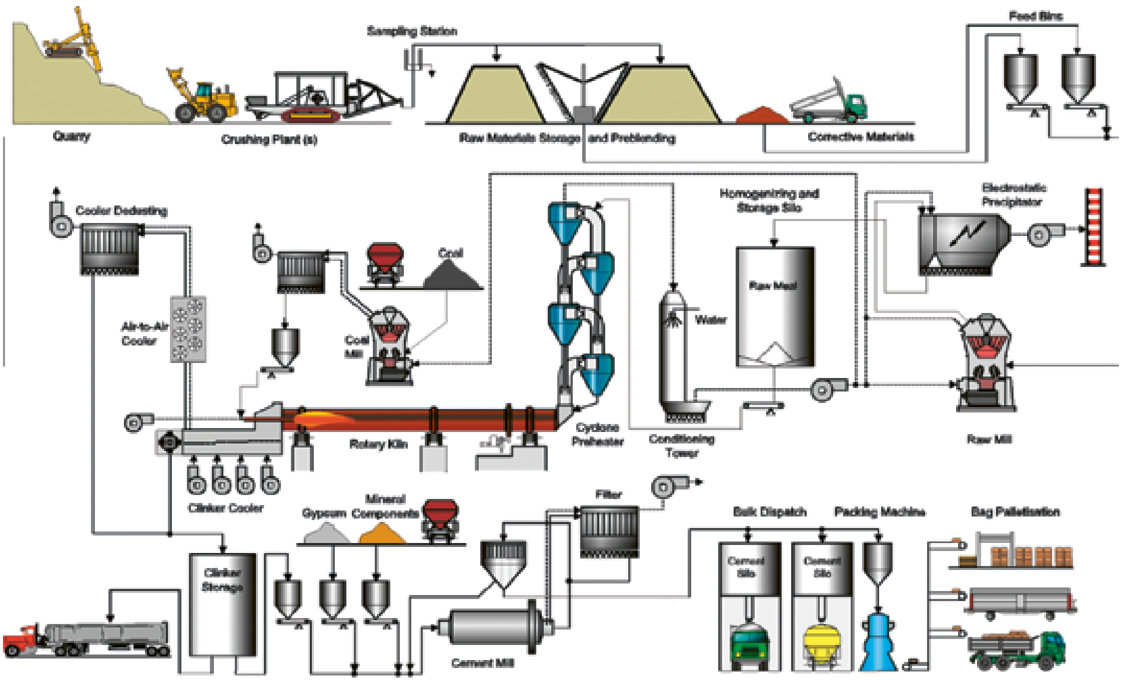


Figure 12: The cement manufacturing process (LafargeHolcim).

The thermal energy required for raw material drying, calcination and sintering reactions has traditionally been provided by fossil fuels such as oil, natural gas, coal and petroleum coke. Various types of waste derived AFs can be used to replace traditional fuels. The *Cement Sustainability Initiative* and *European Cement Research Academy* (CSI/ECRA, 2017) report an average thermal energy demand for cement clinker manufacturing in 2014 of 3.51 GJ/t of clinker with a range of 3.0 GJ/t for modern precalciner kilns and up to 6.0 GJ/t for wet process kilns.

The clinker production process is ideally suited for co-processing of AFR due to its unique characteristics given in *Box 5*.

Box 5 – Advantages of cement kiln characteristics for co-processing alternative fuel and raw material

- The alkaline conditions and intensive mixing between exhaust gas and raw meal in the suspension preheater and raw mill favor the absorption of volatile components from the gas stream. This internal gas cleaning results in low emissions of acidic components such as sulfur dioxide (SO_2), hydrochloric acid (HCl) and hydrofluoric acid (HF). With the exception of very volatile elements such as mercury (Hg) and thallium (Tl) this is also true for 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 oxides (NOx) emissions. Co-processing in many cases even reduces their formation, due to flame cooling in the rotary kiln by the higher moisture content and excess air requirement of alternative fuels, and due to reburning of NOx under reducing conditions in the kiln inlet or precalciner created by the use of coarse alternative fuels.

- The high process temperatures, oxidizing conditions and long residence times contribute to complete destruction of organics (e.g. persistent organic pollutants (POPs)). Typical residence times are a) in the precalciner (2-7 sec at 850 – 900°C), (b) in the kiln inlet (2 – 3 sec at 1,000 – 1,100°C) and (c) in the rotary kiln (6 – 8 sec at > 2,000°C).

- The cement production process has relatively high levels of energy recovery efficiency, generally in the range of 70 – 80% (ECRA, 2017). Waste Incinerators recovering only electricity achieve on average efficiencies of 26%, while incinerators recovering combined heat and power achieve similar efficiencies as cement kilns.

- The cement production process has furthermore high levels of mineral recycling, as neither fly ash nor bottom ash are generated. 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. Also the bypass dust generated in cement plants with high alternative fuel and raw material rates can typically be used as an additive in cement.

2.3.2 AFR Feedpoint Selection

AFR can be introduced at different locations of the clinker manufacturing process. Each of the feedpoints provides different process conditions (e.g. temperature, gas velocity) and is therefore suitable for different AFR qualities. In modern state-of-the-art cement kiln systems fuels are added to the process in mainly two locations, in the precalciner for the calcination reaction and through the main burner/kiln firing at the rotary kiln outlet for the clinkerization reaction. A small portion of the total energy demand can also be added at the rotary kiln inlet, the so-called secondary firing.

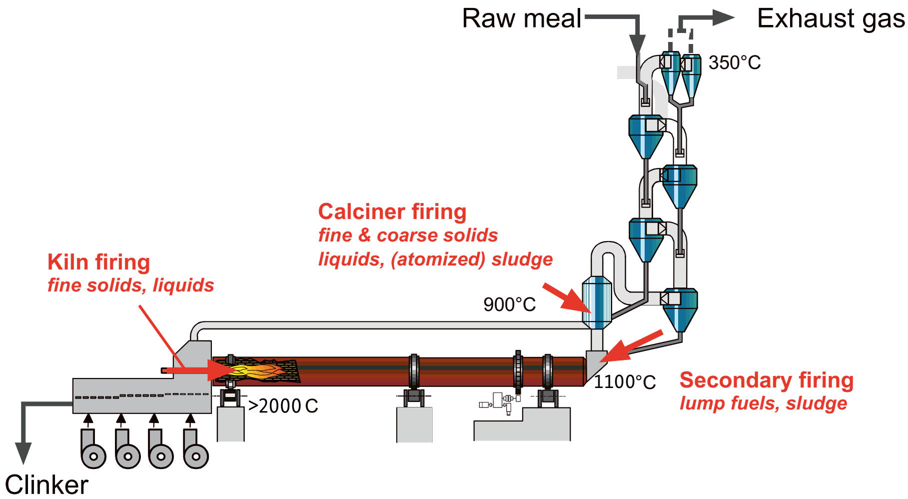


Figure 13: AFR feedpoints of a state-of-the-art cement kiln system (Geocycle).

For solid AFs the feedpoint is mainly determined by their degree of preparation, in particular the particle size and calorific value. For liquid and pasty (sludge) AFs the feedpoint selection depends on how well they can be atomized into more or less fine droplets/particles.

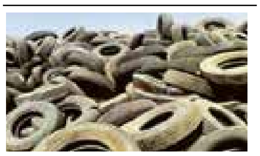
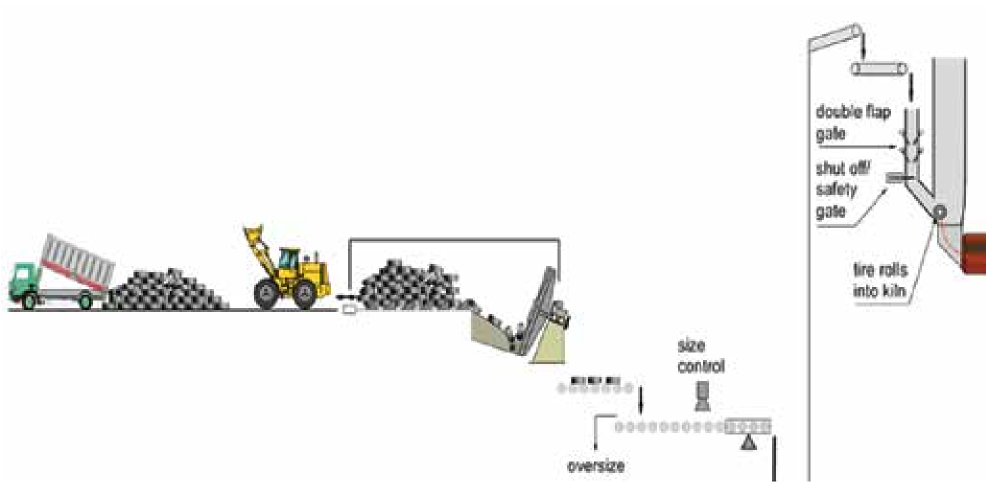
AF Category	Characteristic	Examples	Picture
Lump fuels	Cannot be carried by kiln gases (burns at kiln inlet).	Whole tires, filter cakes, bagged material	
Coarse solids	Can be carried by kiln gases (suitable for precalciner). Pneumatic feeding not possible.	Tire chips, shredded plastics and textiles, coarse RDF	
Fine solids	Can be carried easily by kiln gases (suitable for kiln firing). Pneumatic feeding possible.	Fluff (fine RDF), impregnated saw dust, animal meal, rice husk	
Sludges	Pumpable with piston pump → lump fuel. If atomized by compressed air or sludge rotor → coarse solid.	Petroleum / paint sludges	
Liquids	Can be atomized with compressed air (solid particles in liquid <2-4mm).	Waste oil, solvents, emulsions	

Figure 14: Different AF categories for different feedpoints (Geocycle).

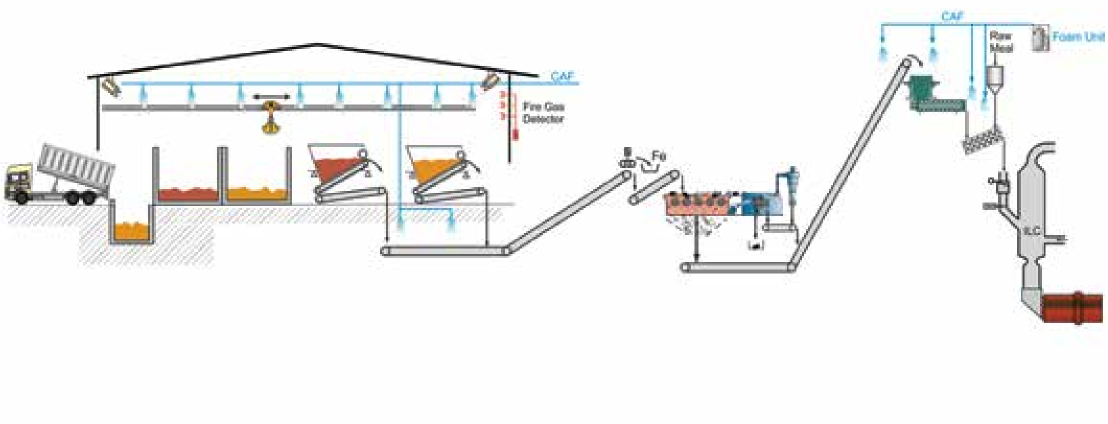
The secondary firing at the inlet of the rotary kiln has the lowest AF quality requirements. Very coarse solid AFs such as whole tires or non-atomized sludges and AFs with low calorific value can be introduced at this feed point. The fuel burns slowly on the material bed in the backend of the rotary kiln when exposed to the oxygen containing kiln gases. However, only a small part of the total kiln energy demand of between 5 – 10% can be fed here. *Figure 15 below* shows an automated system for feeding whole tires to the secondary firing.

Figure 15:
Whole tire feeding to kiln inlet (Geocycle).



The precalciner requires 55 – 65% of the total kiln system energy demand. Coarse solid AFs, atomized sludge and liquids can be added at this feedpoint. Coarse solid fuels need to be small enough to be suspended by the gas flow inside the precalciner to prevent them from dropping down to the kiln inlet. The precalciner is suitable for AFs with medium calorific values, the average calorific value of all fuels should be minimum 11 to 13 GJ/t (ECRA, 2017). Complete combustion is ensured by oxidizing conditions and high gas retention times from 2 up to 7 seconds. *Figure 16 below* shows a typical feeding system for different types of coarse solid AF to the precalciner.

Figure 16:
Coarse solid AF feeding to the precalciner (Geocycle).



At main firing in the rotary kiln 35 – 45% of the total kiln system energy demand is added. Fine solid AF and properly atomized liquids, that can be mixed and suspended with the gases inside the rotary kiln, can be introduced at this feedpoint. In order to achieve flame temperatures of up to 2,000°C required for the clinkerization reactions the average net calorific value of the fuel at the main firing needs to be at least 18 to 22 GJ/t. The high temperature, oxidizing conditions, and gas retention time of 6 – 8 seconds ensure complete burnout. These process conditions make the main firing of cement kilns even suitable for the destruction of stable organic compounds (e.g. POPs). *The figure below* shows a typical feeding system for liquid AFs to the main burner.

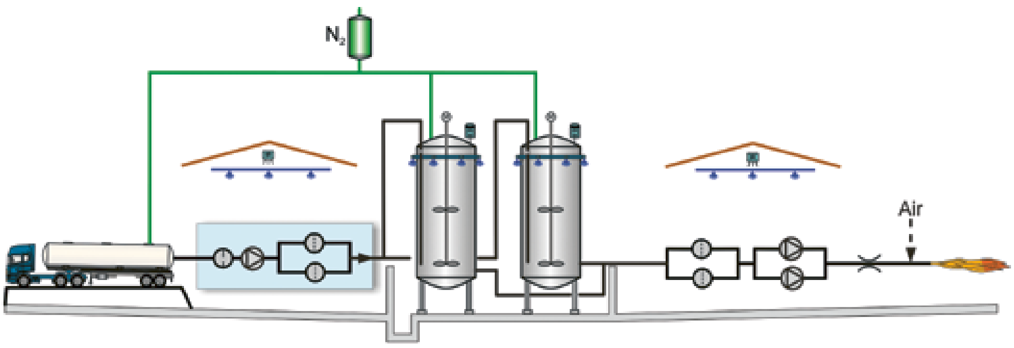


Figure 17: Liquid AF feeding to the main burner/kiln firing (Geocycle).

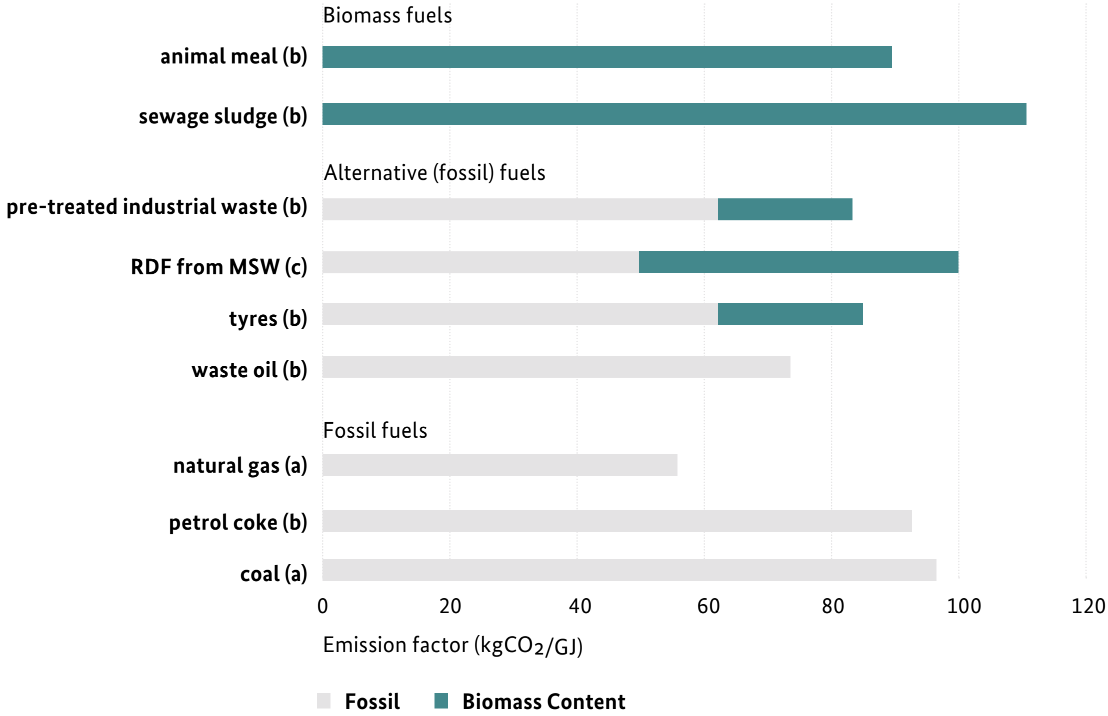
For ARs, the *total organic carbon* (TOC) content is the decisive criteria to select the suitable feedpoint. In case ARs have a TOC content of less than 5,000 ppm, they can be fed-in as any other natural raw material, either to the raw material crusher or to the raw mill. In case the TOC content is higher than 5,000 ppm, a laboratory expulsion test or industrial trial shall be conducted to ensure emissions of *volatile organic compounds* (VOC) are within permitted limits. If the expulsion test or industrial trial results indicate too high VOC emissions, the AR has to be introduced at a feed-point that ensures the complete destruction of the organic content, such as the precalciner or kiln inlet.

2.4 Co-processing and Climate Change

Co-processing can contribute to reducing the carbon intensity of cement production and help the cement industry to meet global climate goals. Cement production contributes around 7% of global carbon emissions, with direct emissions of 2.2 Gt in 2014 (IEA/CSI, 2018). 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, which arise from the calcination reaction ($CaCO_3 \rightarrow CaO + CO_2$) necessary to convert limestone into lime.

Many low and middle income countries continue to use coal or petcoke due to its low price and availability, despite the fact that coal has the highest carbon emissions. Switching to natural gas can already significantly reduce the emissions from cement production, however, due to price and availability this is not always possible. Direct emission reductions from co-processing AFs are dependent on the emissions factor and biomass content, which is shown for different fuel types in in *Figure 18.*

Figure 18: Emissions factors and typical biomass content of different AFs. (a) denotes IPCC default value, (b) CSI default value and (c) is based on a CDM project (*see Annex 2*).



Agricultural residues and other fuels with high biogenic carbon content have typically high emission factors, can however be considered as carbon neutral, due to the absorption of carbon dioxide during their growth. Utilisation of biomass residues such as waste wood, rice husks, dried sewage sludge or animal meal depends very much on availability in local value chains and current usage for such waste streams, but can be a good option for countries where these waste materials are available in abundance. As the calorific value is often lower than conventional fuels, high volumes are needed and long term supply must be assured to recover investment costs in pre-processing or handling equipment, however this can also lead to positive social outcomes as shown in the *case study from Uganda below*. In other cases, municipalities have developed long-term relationships with cement plants to treat their sewage sludge.

AFs 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.

Calculation and reporting on GHG should be done according to the CO_2 and Energy Accounting and Reporting Standard for the Cement Industry of the WBCSD, which is based on IPCC methodology (WBCSD, 2011). VDZ estimates savings of 2.15 Mt of CO_2 through the substitution of coal with AFs derived from wastes in the German cement industry in 2010, based on a typical input mix with 40% biomass proportion (VDZ, 2017b).

Co-processing of waste in cement kilns also enables indirect CO_2 emission reduction through treatment of organic waste fractions that would otherwise decompose anaerobically and produce significant levels of methane (CH_4) on dumpsites or landfills. This is particularly relevant as CH_4 has 25 times the global warming potential of CO_2. Even when landfill gas capture or flaring is applied, only part of the CH_4 (in practice often less than 50%) can be recovered. Promoting proper waste collection and pre- and co-processing can also reduce the amount of municipal waste which undergoes open burning in developing countries – a practice that contributes as much as 5% to global warming through short lived climate pollutants (Wiedinmyer C, 2014). Carbon emission reductions that accrue through interventions that improve local waste management are dependent on the current end-of-life scenario of the waste (recycling, incineration, sanitary landfill, dumpsite, open burning), as well as on the biogenic carbon content of the waste (*see Annex 3*).

Calculation of CO_2 reduction through methane avoidance is difficult to attribute to cement production due to the lack of verifiable measurement methodologies for hypothetical emissions avoidance. However, the avoided emissions can be significant, particularly when co-processing forms part of an integrated waste management approach. Where suitable systems are set up to segregate at source and remove the organic fraction, major reductions can be achieved through composting, recycling and co-processing of the non-recyclable fraction from MSW which is pre-processed into RDF.

A number of projects to increase the use of AFs have been initiated under the *Clean Development Mechanism* (CDM), which look at integrating co-processing into the waste management system. Following the expiration of the CDM mechanism, *Nationally Appropriate Mitigation Actions* (NAMAs) have become a financing instrument which could support GHG reductions in MSW management, particularly since such interventions also bring with them important environmental and health benefits that can contribute to meeting the SDGs. However, experience with waste NAMAs around the world remains so far limited. Further positive developments could result from an appropriate carbon price, which makes using fossil fuels unattractive and AFs more competitive. In comparison to other technologies to reduce the emissions from cement plants, use of AF is a relatively low investment cost option (Mckinsey & Company, 2013). Major GHG reductions can also be achieved through utilization of slags and fly ashes in cement grinding, which due to their cementitious properties enable reduction of the clinker content in blended cement.

Case Study 4: Developing coffee husks as an alternative fuel in Uganda

Coffee is a major cash crop in Uganda, with up to 20% of the population earning all or a large part of their income from coffee production. The coffee milling process generates coffee husks, an agricultural residue that is commonly dumped or burnt for disposal. Coffee husks can however also provide a suitable alternative fuel source for cement plants. Since the mid-2000s the Hima cement plant in Uganda has utilized this agricultural residue as an energy source for both the cement kiln and pozzolana dryer, achieving more than 55% thermal energy substitution. As a result, the plant has been able to reduce its reliance on imported fossil fuels, which must be transported 1,500 km by road from Mombasa in Kenya.

As uptake of this alternative fuel expanded, the plant considered ways to improve the long-term sourcing strategy, as many of the coffee husks still required transportation over large distances. The local availability of coffee husks was limited as the farmers couldn't afford the high prices for coffee seedlings. After consultation with local stakeholders, the plant partnered with the Uganda Coffee Development Association to launch a program to support the development of coffee production near the plant, with the aim of raising incomes for local farmers and at the same time increasing the generation of biomass residues locally. Seedling nurseries were set up from which seedlings could be purchased for a sixth of the usual price. As a result, 45,000 farmers signed up and nearly 17 million seedlings were distributed between 2012 – 2015.

Substituting fossil fuels with locally available agricultural residues has an important impact on the climate emissions of the plant, whilst also enabling poverty reduction. The Hima plant expects to recover 20,000 t of agricultural residues per year as a result of their coffee program, which make a significant contribution to the 100,000 t of climate neutral biomass fuel used each year by LafargeHolcim in Uganda. An estimated 150,000 t per year of CO_2 are saved through using biomass.

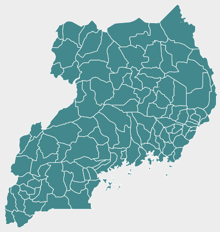


Photo:
Coffee farmers in Uganda.

2.5 Integrated Solid Waste Management Planning

The approach of *Integrated Solid Waste Management* (ISWM) is increasingly applied by policymakers internationally. ISWM focuses on the key physical elements such as waste collection, treatment, and disposal following the waste hierarchy. Governance aspects need to be considered to establish a well-functioning system: the system should be inclusive, enabling stakeholders to contribute; be financially sustainable and be implemented by sound institutions and proactive policies (Wilson, 2013).

Pre- and co-processing is usually not a stand-alone nor the primary waste management solution, but can play a role in an integrated waste management strategy. Cement producers save on fossil fuel and raw material consumption, contributing to a more sustainable production, as well as optimize production cost. Meanwhile authorities and communities can utilise existing industrial facilities for waste treatment, reducing the need for additional investments, with the presence of already qualified staff being an additional advantage[2]. Through co-processing, the cement industry can provide value added to waste systems operated by municipalities, and contribute to better waste management outcomes for stakeholders in the industrial, commercial and agricultural sectors.

If the host community to the cement plant already has an integrated waste management strategy or master plan, then modifying or amending this plan is an important first step in exploring the feasibility of pre- and co-processing as a recovery strategy[3]. The impact of the introduction of pre- and co-processing on existing treatment and final disposal options should be evaluated in the framework of an update or upgrade to the existing waste management plan. Where no current plan or strategy is in place, municipalities should strive to develop one and analyse how pre- and co-processing can contribute to the local waste management situation. The cement company proposing co-processing, together with the potential operator of pre-processing, may consider to support the development of such a plan with inputs from baselines, as long as local stakeholders and politicians can be assured of the neutrality and professionalism of the process and the resulting documents.

In most cases such a plan will document and evaluate:

- Existing collection capacities
- Existing treatment capacities
- Institutional and human skills knowledge
- Financial sustainability
- Legal and institutional framework
- Social aspects
- Environmental aspects.

Although not always legally required, the establishment of a baseline assessment or zero-measurement by the potential operator is highly beneficial as it corresponds to social/environmental impact assessment and provides useful information for the permitting process and monitoring of pre- and co-processing impacts. Such a baseline should measure and document the key parameters in the waste management system (the service chain) and the value chains already serving as markets for recyclables, organics, and other waste streams, besides the physical and geographical baseline conditions (e.g. odor and noise levels). It should document what is working and what is not working in the local landscape of solid waste management and recycling. Transparent analysis of strengths, weaknesses, opportunities and threats in the jurisdiction, city, or region is a path to being able to answer the key questions necessary to start a co-processing initiative. The framework of Integrated Sustainable Waste Management is one relatively accessible approach to preparing a participatory baseline. In the case of a proposal for co-processing, key elements of such a baseline process would include developing answers to the questions provided in *Annex 12*. Producing a baseline that answers these questions should provide a clear indication of whether co-processing has a value to add to the solid waste system, and whether the availability of AFR from waste in this system has a value to the cement producer. If the answer to both of these is positive, the boundary conditions for beginning a co-processing initiative are present.

2 For an overview of where co-processing relates to other waste-to-energy technologies and when these different technologies can be applied, see GIZ Guide on Waste-to-Energy Options in Municipal Solid Waste Management (GIZ, 2017).

3 For further information on waste management planning see: *http://ec.europa.eu/environment/waste/plans/index.htm*

2.6 Organization of Pre- and Co-processing

The pre- and co-processing value chain may be fully integrated and managed by one entity, or separate entities may manage different activities e.g. waste collection, pre-processing and co-processing. In mature waste markets, public or private actors usually already operate collection, transfer and transport. Where there are strong markets for organics or recyclables, some form of post-collection sorting or processing of recyclables may be present, and this infrastructure may also be suitable for pre-processing of waste fractions into AFR. Pre-existing claims, as well as economic factors, will largely determine whether one or more parties control the entire service chain, or whether control and earning models are spread over a variety of enterprises and public actors.

A typical operating model for municipal waste could consist of:

1. Collection by municipality
2. Landfill operation by private waste management company
3. Separation of heavy fraction (organics), recyclables and light fraction by informal waste worker cooperative at dedicated locations.
4. Pre-processing (mechanical treatment) of light fraction for AF production by private waste management company
5. Co-processing of AF by cement company.

Where the solid waste system is not well developed, the lack of waste management operations and established stakeholders in different market niches may lead to a situation where the cement producer integrates into larger parts of the value chain. The disadvantage of this is however, that waste management is not the core business of the cement industry and there is a risk that they may focus on the most valuable or high calorific value waste streams. This increases competition with recycling and also may make the integration into an overall waste management concept more difficult. Therefore, it is important to apply the first principle of these Guidelines: respecting the waste hierarchy and allowing for a dynamic relation between recycling and co-processing is important to mitigate risks.

In case there are several separate entities in the service chain, this can lead to more competitive and efficient supply chains, but carries with it potential disadvantages of fragmentation, poor economies of scale, and a weak business case. Additional risks are a growing administration and loss of traceability of the material flows. *The figure below* demonstrates the pro and cons of different value chain approaches from a cement company perspective.

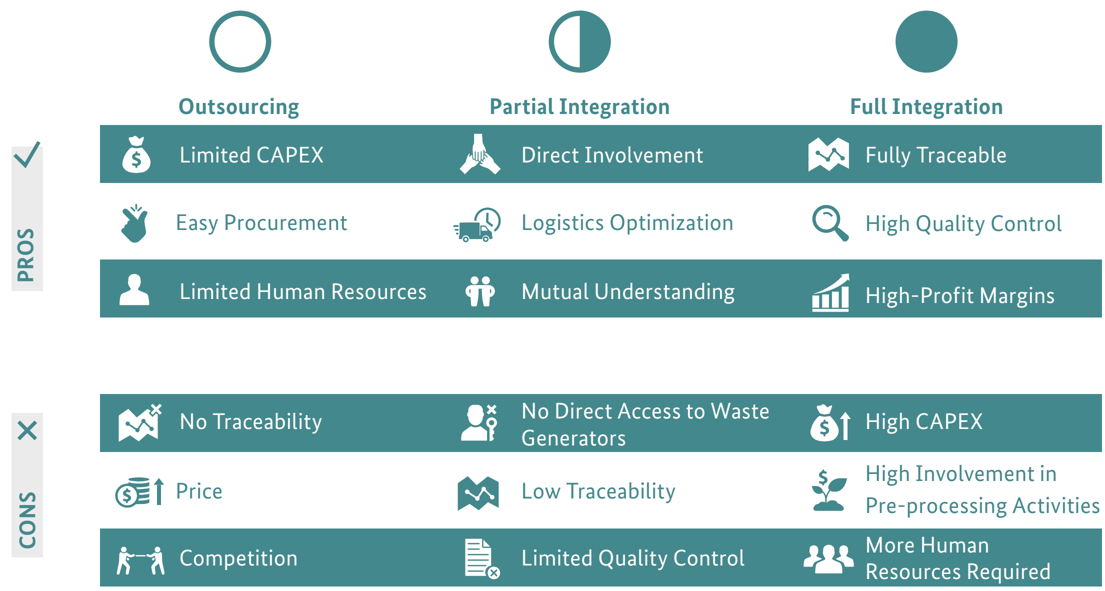


Figure 19: Advantage and disadvantage of the various integration models (IFC, 2016).

The interest of the cement company will in the first instance depend on their assessment as to whether capturing and co-processing the non-recyclable fractions available for AFR will be cost competitive and environmentally beneficial, as compared with the substituted fuels and raw materials. Parallel considerations for the waste management or environmental or political authorities will determine whether there is an interest from the city or region to cooperate in a co-processing initiative, and to take the steps that are necessary to mobilise pre-processing and produce AFR. Only when both "sides" see an advantage will there be a chance of a successful co-processing initiative. For more detail on financing aspects, *refer to section 3.6*.

PART 3

REQUIREMENTS FOR ENVIRONMENTALLY SOUND PRE- AND CO-PROCESSING

Specific guidance: Part 3 represents the most important part of the Guidelines: setting out the requirements for sustainable and environmentally sound pre- and co-processing. This section covers national, legal, and institutional frameworks (3.1), environmental emissions control and monitoring (3.2), operational procedures to ensure quality control (3.3), health and safety (3.4), decision making based on mutual benefit, stakeholder communications and engagement with the informal sector (3.5), and the importance of having robust financing in place (3.6). The overarching principles and requirements corresponding to each subject are laid out at the beginning of each section. In all, there are 16 specific requirements corresponding to the eight guiding principles. A closing chapter details next steps for implementation: capacity development and how to apply specific sections of the Guidelines (3.7). The overarching principle "Respect the Waste Hierarchy and Circular Economy" must be followed (*See Part 1*).

3.1 Legal and Institutional Aspects

Principle 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 an 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.

Requirement 1 — **An appropriate legal framework needs to be established**

- Pre- and co-processing shall be integrated as a viable waste management solution into the legislation concerning environmental protection, public health and waste management.
- Clearly defined legally-binding regulations and standards are necessary to guarantee legal security and to assure a high level of environmental protection.
- Competent and empowered authorities shall ensure fair and consistent law enforcement.

Requirement 2 — **All relevant stakeholders shall be involved during the permitting process**

- Environmental and Social Impact Assessments shall be used to identify and quantify potential impacts of waste and AFR on the environment, human health and local value chains prior to operations. This data will also be used to develop a baseline, which shall be regularly re-assessed as the process develops.
- *Best Available Technology* (BAT) should be considered and applied.
- Operators of waste treatment facilities and cement plants shall provide all information to enable the stakeholders to evaluate the pre- and co-processing activities.

3.1.1 Legal Framework

National policies and laws always frame the basic principles and standards under which pre- and co-processing should take place. Without legally binding requirements, the authorities will not be able to control compliance and to enforce high levels of environmental and public health protection, while plant operators will not have a clear framework in which to operate.

The regulatory framework should reflect the capacities of environmental authorities, cement and waste management sector in a specific country. Complex standards are difficult to implement and enforce, particularly in developing countries. Clearly defined criteria that are easy to evaluate and to apply are more appropriate. To integrate pre- and co-processing into the national industrial, environmental and waste policies and laws, the regulatory bodies, waste management sector, cement industry and other stakeholders (e.g. municipalities, academic institutions, NGOs) should provide a country- and sector specific input for the national institutions formulating laws and regulations.

In cases where no existing legislative and/or regulatory framework can be adapted for pre- and co-processing, operators of pre-processing facilities (drawn from the waste management sector or elsewhere), together with cement producers intending to implement co-processing, should propose a regulatory framework from other countries with comparable or higher levels of development as measured by gross domestic product, waste generation, and waste management system development. The operators should prepare a preliminary set of documentation compliant with the proposed system, with reference to *Best Available Techniques* (BAT) before starting any activities.

If the local and national authorities are not able or willing to develop a relevant set of legal and regulatory instruments, the company may consult with these authorities and gain permission to apply for a permit under the general environmental law in force, applying internationally accepted standards.

3.1.2 Institutional Framework

Experience from countries that allow pre- and co-processing shows that the permitting process, inspection and controlling functions are preferably managed within a single regulatory agency. However, if the same governmental institution also takes on other roles in the system, particularly that of waste operator, then the potential for conflicts of interests arises. Therefore, budgetary and judicial independence and transparency of the regulator are essential to enforce standards equally on both private and public sector operators.

The regulatory agency should be empowered and have an adequate technical background, strong management, and well-trained and well-equipped staff. A lack of awareness or resources for control and inspection can lead to poor law enforcement. However, if the authorities do not have all relevant knowledge and experience, external expertise from reliable companies in the cement and waste management sector and consultants from independent bodies, such as universities, NGOs, associations, and/or consulting firms can be considered.

3.1.3 Permitting Process

Operators of waste treatment facilities intending to pre-process waste and cement plant operators intending to co-process AFR have the responsibility to apply for a permit. A well-prepared permit application for pre- or co-processing should provide detailed descriptions of all relevant information on the waste treatment facility or cement plant as well as the quality of all waste or AFR designated for pre- and co-processing, including information on:

- Waste generator/Source of waste
- Already treated waste/AFR type
- Expected additional volumes per waste/AFR type
- Waste/AFR treatment, handling and storage installations
- Waste/AFR chemical and physical properties
- Waste/AFR quality control and assurance plan
- Traditional raw materials and fuels used (co-processing)
- AFR feeding point into the kiln process (co-processing)
- Main equipment specifications and operating procedures
- Current and expected levels of emissions to air, water and soil
- Available emission monitoring and abatement technologies
- Applicable H&S standards
- Storage and treatment capacity for contaminated runoff water or for contaminated water arising from spillage or fire-fighting operations
- Emergency response plan
- Public consultation procedure.

When the application is completed, the authorities will review and give feedback. Continuous communication with the authorities is recommended in order to avoid delays in the permitting process. At the same time an open communication and regular consultations with the public will help to reduce possible friction and misunderstandings (*see also Annex 8 and Annex 9*).

The roles and responsibility of the operator making the application include:

- Establish contact with the competent authority and statutory consulting authority.
- Prepare application form.
- Perform *Environmental and Social Impact Assessment* (ESIA).
- Initiate public participation early so that concerns can already be taken into consideration in the permit application form.

The roles and responsibilities of the permit issuing authority – typically an environmental ministry – would normally include the following:

- Have transparent rules about which permits are required for pre-processing (likely to fall under the waste permitting jurisdiction) and which are required for co-processing (more likely to fall under industrial operations).
- Publish and provide in advance, all relevant information on the application forms; manner of submission; dates; key milestones in the permitting process; expected elapsed time from submission to key milestones; the nature of information that must be provided; in what form; and with what types of proof or due diligence.
- Publish (and continuously update what is published in case the rules change) the criteria for permitting, anchored in legislation and regulations.
- Consult with other authorities sharing jurisdiction, for example, those regulating health, transportation, commerce, environment, climate, or labour.
- Make it clear whether the permit application requires ESIA, and publish transparently the information on dates and criteria for participating in hearings, or making written comments or legal objections during the public comments.
- Evaluate ESIA, and other parts of the relevant permit applications following the regulations in a transparent way.
- Approve the draft permit or return it for further development, according to transparent and published criteria.
- Admit all objections and facilitate dialogue and consultation with the objectors.
- At a point at which the permit application complies with laws and rules, approve and issue (with additional stipulations i.e. imposition, condition, time limitation, reservation as to revocation), or if indicated, deny the permit.

Permits should define the waste and AFR types licensed for pre- and co-processing. Generic co-processing permits should only be issued for AFR types with defined characteristics and a track record of successful long-term use in cement plants (e.g. tires) or for AFR types prepared by pre-processing facilities according to the specifications and requirements of the cement plant. Systematic and periodic inspections by the permit issuing authority should be conducted to ensure compliance with regulatory requirements.

Further guidance regarding the permitting process within or under the sphere of influence of the European Union can be found in "Doing the Right Things for Permitting" of the EU network for the *Implementation and Enforcement of Environmental Law* (IMPEL, 2015).

Case Study 5: How to master the permitting process in Argentina

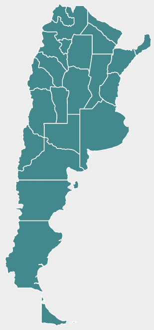


Photo: Cement plant staff preparing permitting documents.

Within the Argentinian legal and environmental framework, the State is responsible for establishing the rules of environmental quality, whereas the provinces are responsible for complementing such rules. In this sense, the Law 24051 on hazardous waste is a national law, and provinces and municipalities are mandated to follow the legal prescriptions.

In order to comply with the environmental regulations for operation, Geocycle Argentina needs to obtain annually more than 40 environmental permits, 30 of which correspond to authorizations specific to hazardous waste operations and transport activities to be derived from national, provincial and municipal jurisdictions of the states Córdoba, Jujuy and Mendoza. Failure to obtain these permits, or to get a new authorization once a permit expires, prevents the entry of waste material to Geocycle facilities. Many of these permits need to be applied for 90 days before the expiration date. In most of the cases, however, even if all deadlines and established requirements are met, the regulatory body issues authorizations only a long time after the expiration date. This not only hinders the continuation of Geocycle operations, but also triggers negative economic impacts and affects marketing and customer relations.

Geocycle Argentina complies with the 90 day permitting time, but to improve processes, also took the following steps:

- an advocacy process was initiated to better inform officers from environmental control bodies and to make them aware of Geocycle's work, values, the socio-economic and environmental benefits, but also the economic and environmental impacts of delays.
- an open-door policy for involved stakeholders, including local and provincial officers, to inform them about the processes and plant operations especially on all aspects related to environmental concerns.
- Lead by the *Asociación de Fabricantes de Cemento Portland* (AFCP) a stakeholder platform as well as a co-processing committee has been initiated to actively participate in discussions about new legislation with national environmental agencies.

Lessons Learnt: It is essential to maintain a regular and open dialogue with the different regulatory bodies in order to clarify any concerns that might delay the issuance of permits. While the process for obtaining permits in Argentina is highly bureaucratic, companies can join efforts to help authorities to improve their processes and expedite permits issuance. Obtaining all permits within the required time limits without affecting the continuation of operations in its three plants, continues to be a major challenge for Geocycle Argentina. However, they are confident that the approach to voluntarily apply for permit renewal ahead of set timelines including a regular and open dialogue with regulatory bodies will strongly support the permitting process.

3.2 Environmental Aspects

Principle II

Environmental Aspects

- Prevent or keep at a minimum additional emissions and other negative effects on the environment from pre- and co-processing.
- 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).

Requirement 3

Pre- and co-processing shall not have negative impacts on emissions

- All AFs shall be fed into the high-temperature zones of the kiln system (i.e. main firing, secondary firing, precalciner firing). The same is true for alternative raw materials with elevated amounts of volatile organic matter.
- Pollutants in alternative fuels or raw materials for which the cement process has insufficient retention capability (e.g. Hg) should be limited.

Requirement 4

Emission monitoring is obligatory

- Emissions must be monitored regularly in order to demonstrate:
  - I. compliance with the national regulations and agreements
  - II. compliance with company policies and directives
  - III. the reliability of the quality control of the input materials.

Requirement 5

The environmental performance of the cement products (concrete, mortar) shall not deteriorate

- The heavy metal concentration of the final products shall not have any negative impacts, as e.g. demonstrated with leaching tests.
- The quality of concrete shall allow end-of-life recycling.

3.2.1 Relevant Pollutants

National emission standards shall be applied to pre- and co-processing by the concerned authorities and implemented by permits. In many countries, industrial emissions standards already exist but do not specifically cover emissions from waste pre-processing facilities and cement plants co-processing AFR. Each country should define its relevant pollutants and emission limit values, taking into consideration the overall economic and industrial development.

In Europe, for example, the relevant pollutants and emission limit values are defined by the *Industrial Emissions Directive* (IED) (Directive 2010/75/EU), and the *Pollutants Release and Transfer Register* (PRTR)[4]. The latter covers 91 pollutants and gives reporting threshold values for releases to air and water. Similar pollutant registers exist in Australia (National Pollutants Inventory), Canada (National Pollutants Release Inventory), and the US (Toxics Release Inventory).

For waste management activities a wide range of potential air and water pollutants are mentioned in the guidance document to the PRTR, depending on the nature (hazardous or non-hazardous) and type of waste treated (E-PRTR, 2006). According to the EU Waste Treatment BREF (Brinkmann et al., 2018), the following pollutants should be considered as relevant in the context of pre-processing facilities for the production of AFs and raw materials by mechanical, biological or physico-chemical treatment of waste:

Emissions to air (pre-processing):

- Dust, for all waste treatments
- *Total volatile organic compounds* (TVOC), for biological waste treatment
- *Hydrogen sulphide* (H_2S), for biological waste treatment
- Ammonia (NH_3), for biological and physico-chemical waste treatment.

Emissions to water (pre-processing):

- *Chemical oxygen demand* (COD), for all waste treatments
- Hydrocarbon oil index and phenol index, for physico-chemical waste treatment
- Metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn), for mechanical-biological and physico- chemical waste treatment
- *Total nitrogen* (total N), for biological waste treatment
- *Total organic carbon* (TOC), for all waste treatments
- *Total phosphorus* (total P), biological waste treatment of waste
- *Total suspended solids* (TSS), for all waste treatment.

It is unlikely that emissions to air, soil, and water from pre-processing facilities reach PRTR threshold limit values for any of the pollutants. Nevertheless, emission monitoring and reporting should be regularly performed according to local applicable regulations.

For cement kilns, emissions to air are usually of highest importance, while only few cement plants reach threshold values for releases to water. Emissions considered to be relevant by the IED and PRTR include:

- Dust
- SO_2
- NOx (sum of NO and NO_2)
- CO
- TVOC
- All inorganic gaseous chlorine compounds expressed as HCl
- All inorganic gaseous fluorine compounds expressed as HF
- NH_3
- Dioxins and furans (PCDD/F)
- Benzene
- Metals (Hg, Tl, As, Sb, Cd, Cr, Cu, Mn, Ni, Pb, Zn, V).

Due to the volatile nature of mercury, special attention should be given to the mercury content of materials used for clinker production and corresponding operational procedures.

4 *https://prtr.ec.europa.eu*

Box 6: Mercury (Hg)

Hg is bioaccumulative and highly toxic to humans in all its chemical forms. It is a comparatively rare element, with an average concentration in the earth's crust of only 0.000005%. It is found both naturally and as an introduced contaminant in the environment. Because of its volatile nature and its presence in fossil fuels and natural raw materials being used in many industrial processes, Hg is released into the atmosphere from a wide variety of anthropogenic emission sources.

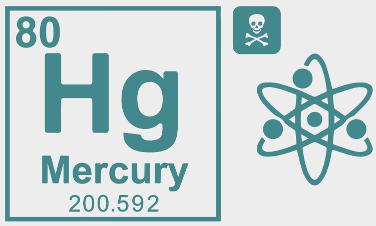
In August 2017, the UN Minamata Convention on Hg entered into force. The convention recognizes Hg as a chemical of global concern due to its long-range atmospheric transport, its persistence in the environment, its bioaccumulation potential and its significant effects on human health and the environment (UNEP, 2017a).

Governments that are parties to the Convention are legally bound to take measures to protect the environment and human health from the harmful release of Hg by addressing mercury throughout its lifecycle. This includes controls on mercury emissions to air and releases into water. The convention seeks to reduce all Hg emissions, including those from industrial processes, among others also from cement production.

Hg is found in all cement raw materials and fuels. An additional source of Hg in the kiln can be the co-processing of Hg-containing alternative fuel and raw material. Due to its volatile nature, Hg is not retained in the kiln system and subsequently captured in the clinker matrix. Instead, it forms gaseous compounds that are only partially retained by condensation on the raw material in the raw mill and dust collector. In order to reduce Hg emissions, it may also become necessary to limit the Hg input from raw material and fuels into the kiln system. Hg emissions can be reduced by extracting filter dust during direct operation and feeding the filter dust to the cement mills.

The European IED limits Hg emissions to 0.05 mg/Nm3 @10% O_2. In the United States of America, the National Emission Standard for Hazardous Air Pollutants sets a limit for new cement plants of 21 lb per million tons of clinker and of 55 lb per million tons of clinker for existing plants (EPA, 2006). The Standard for *Commercial Industrial Solid Waste Incineration Units* (CISWI)[5] sets a limit of 0.011mg/Nm^3 @ 7% O_2 (EPA, 2016).

In order to comply with these limits, all input materials into the cement kiln need to be regularly analyzed for their Hg content. Responsible use of AFR includes testing of incoming materials for Hg contents and refraining from using them if Hg content is too high.



POPs are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. Because of their persistence, POPs bioaccumulate in living organisms with potential adverse impacts on human health and the environment.

The Stockholm Convention on POPs mentions cement kilns burning hazardous waste as a potential source for the formation and release of POPs (UNEP, 2017). However, a comprehensive study on the formation and release of POPs in the cement industry carried out by WBCSD clearly points out that elevated POP formation and release levels have only occurred in long wet and dry kilns, and these are no longer considered as state of the art technology (WBCSD, 2006). Furthermore, cement kilns are recognized by the Basel Convention Technical guidelines as a suitable waste management technique for the destruction of POPs in wastes when performed according to BAT while meeting requirements set out for input, process and emission controls (UNEP, 2011). For the co-processing of waste classified as POP, a trial burn must be performed to demonstrate 99.9999% *destruction and removal efficiency* (DRE). A detailed description of the procedure for DRE trial burns can be found in *Annex 10*.

5 https://www.epa.gov/stationary-sources-air-pollution/commercial-and-industrial-solid-waste-incineration-units-ciswi-new

Box 7: Dioxins and Furans (PCDDs/PCDFs)

PCDDs/PCDFs are compounds that are highly toxic environmental *persistent organic pollutants* (POPs). Because dioxins and furans refer to a broad class of compounds that vary widely in toxicity, the concept of a toxic equivalency factor has been developed to facilitate risk assessment and regulatory control. In reference to their importance as environmental toxicants the term dioxins and furans is used to refer to the sum of compounds (as TEQ) which demonstrate the same specific toxicity as dioxin 2,3,7,8-*tetrachlorodibenzo-p-dioxin* (TCDD). These include 17 PCDDs/PCDFs and 12 PCBs.

Formation of PCDDs/PCDFs involves many complex reactions and a complete understanding of the reaction chemistry is not yet established. PCDDs and PCDFs can form in cement kilns in the preheater and air pollution control device if sufficient chlorine, chloro-aromatic precursors and/or volatile hydrocarbons from incomplete combustion or raw materials are available. The formation of dioxins and furans is known to occur primarily from heterogeneous, surface-catalyzed reactions of precursors or de novo synthesis in the temperature window between 250 – 450°C. Thus, it is important that the exit gases are cooled rapidly to lower than 200°C. Modern preheater and precalciner kilns have this feature already inherent in the process design.

WBCSD evaluated around 2,200 dioxins and furans (PCDDs/PCDFs) measurements made from the late 1970s until recently. The data indicate that cement kilns can normally comply with PCDDs/PCDF emission levels of < 0.1 ng TEQ/Nm^3 at 10% O_2, which is the limit value of the European Industrial Emissions Directive for cement kilns co-processing AFR. Co-processing of alternative fuels and raw materials, fed to the main burner, kiln inlet or the precalciner does not seem to influence or change the emissions of POPs (WBCSD, 2006).

The most important primary measures to ensure compliance with a dioxins and furans (PCDDs/PCDFs) emission level of 0.1 ng TEQ/Nm^3 at 10% O_2 are:

- Quick cooling of the kiln exhaust gases to lower than 200°C in long wet and long dry kilns. Modern preheater and precalciner kilns have this feature already inherent in the process design.
- Avoid feeding of alternative raw materials as part of natural raw mix if it contains volatile organic compounds.
- Avoid feeding of alternative fuels during start-up and shut down of the cement kiln.

Photo: Cooling and scrubbing of exhaust gases in suspension preheater.

3.2.2 Emission Reduction Techniques

Emissions to air from pre-processing facilities depend on the types of wastes treated and the processes used. Emissions to air from dust and organic compounds should be expected and proper abatement techniques should be in place. Typical ranges for emissions to air from cement kilns, and appropriate reduction techniques are explained in detail in the BREF document for the Production of *Cement, Lime and Magnesium Oxide* (CLM) (European Commission, 2013). Since there is no significant change in emissions with sustainable co-processing this also applies for co-processing:

- Diffuse dust: cover bulk storage areas or stockpiles, use open pile wind protection, use water spray and chemical dust suppressants, ensure paving, road wetting and housekeeping.
- Channeled dust: electrostatic precipitators, fabric filters, hybrid filters.
- Volatile organic and odorous compounds: adsorption, biofilter, thermal oxidation, wet scrubbing.
- SO_2: optimising the raw milling process, adsorption, wet scrubbing.
- NOx: primary techniques (flame cooling, low NOx burners, process optimisation), staged combustion (conventional or AFs), *selective non-catalytic reduction* (SNCR), *selective catalytic reduction* (SCR) depending on appropriate catalyst and process development in the cement industry.
- CO, TVOC and benzene: optimising the combustion process, avoid feeding raw materials with a high content of VOC into the kiln system via the raw material feeding route.
- HCl and HF: using filter dust removal techniques, chlorine gas bypass techniques, adsorption.
- NH_3: optimize ammonia slip due to unreacted ammonia from the NOx reduction by SNCR.
- PCDD/F: carefully selecting and controlling of input materials (e.g. chlorine, copper and volatile organic compounds in raw materials and chlorine, copper in fuels), limiting the use of AFR which contain chlorinated organic materials, avoid co-processing during kiln start-up and shutdown.
- Metals (Hg, Cd, Tl, As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V): limiting the content of relevant metals in input materials, using effective dust removal techniques.

Contaminated water from pre-processing facilities should be captured and treated responsibly. Releases to surface water and groundwater depend on the types of wastes treated and the processes used. According to the degree and nature of the pollutants and to the output (surface water, on-site water treatment, collective industrial water treatment, or public sewer system), a combination of the following different reduction techniques may be used:

- Water treatment: settling, hydrocarbon/oil/sludge separators, adsorption, physical-chemical treatment, biological treatment, thermal treatment (for highly polluted water).

Wastes generated by such reduction techniques (used activated carbon, sludge, hydrocarbons, oils etc.) can in many cases also be co-processed, otherwise these have to be directed to external treatment plants. Suitable abatement techniques and engineering measures should be put in place for soil and groundwater protection, such as an appropriate geomembrane as a ground seal.

Cement plants do not emit industrially polluted water, but only produce domestic wastewater from various plant sections. These effluents are typically discharged to captive or public wastewater treatment facilities.

In both pre-processing facilities and cement plants special attention should be paid to being able to manage potentially polluted firefighting water. Should there be a fire, it is possible that this water may become contaminated with firefighting media and fire residues. This contaminated water should be captured and responsibly disposed of.

3.2.3 Emissions Monitoring and Reporting

Pre-processing facilities should be inspected and air emission spot measurements taken by a competent independent testing laboratory once every six months. The coverage of the inspection and air emission testing shall be defined in the permit of the pre-processing facility. The testing company should comply with the requirements of local regulations, both with regards to competence and reporting.

Odor measurements can be complex and unreliable. However, a baseline investigation of the odor and noise levels should be performed prior to construction or start up of waste treatment facilities in case of future complaints from neighbors, allegations and liabilities.

Cleaning water, process water and firefighting media may be a significant source of pollution to effluent water. Discharge limit values for pollutants should be an integral part of the permit, and compliance must be monitored and reported. Emissions to water should be monitored once every month.

With the exception of accidents, emissions to soil and groundwater are not expected. However, a baseline investigation of the groundwater and soil pollution level should be performed prior to construction or start up of waste treatment facilities in case of future allegations and liabilities.

Emission monitoring and reporting of cement plants should include all the components outlined in *Table 3 below*. These requirements for air emissions monitoring at cement plants are ambitious but recommended as standard for air emissions regulations.

Table 3: Cement plant (co-processing) air emissions monitoring method for relevant pollutants.

Component	**Monitoring Frequency**
Dust, SO_2, NOx, CO, VOC	Continuously
HCl, NH_3, Hg, Tl, Cd, As, Cr, Cu, Sb. Ni, Pb, Zn, V, benzene, dioxins and furans	Periodic measurements at least once a year

Reliable online emission monitors should be used for continuous measurements. For periodic spot measurements competent national or international service companies should be selected.

During the periodic spot measurements, the service companies should also measure dust, SO_2, NOx, CO and VOC for comparison of the results with the respective averages of the continuous measurements in the same time period. In case of significant deviations, continuous and discontinuous measurements should be checked for accuracy.

The air and water emission measurements should be carried out in accordance with EN or ISO standards, national or other international standards that ensure the provision of data of an equivalent scientific quality. The European BREF Report on Monitoring of Emissions to Air and Water from IED Installations (Brinkmann et al., 2018) provides a good overview about the different standards and some general aspects of emission monitoring such as monitoring regime, quality assurance and reporting.

Care should be taken during waste and AFR *storage, handling and transfer* as some pollutants could leach into soil and groundwater. The storage, handling and transfer areas for waste and AFR at the pre- and co-processing sites should be designed according to standard industry approaches (adequate capacity, safe operation) and should consider the procedures *below*:

- Handling and transfer of waste and AFR are carried out by competent staff.
- Measures are taken to prevent, detect and mitigate spills.
- Operation and design precautions are taken when mixing or blending wastes.

Further recommendations on how to reduce emissions from storage, transfer and handling of solids and liquids can be found in the European reference document on BAT on Emissions from Storage (European Commission, 2006).

Box 8. Transparency in Emissions Monitoring

Effective monitoring and control of emissions and other potential sources of problems potentially arising from the introduction of pre- and co-processing, can best be conceived as a participatory and inclusive process. The interests of neighbours and abutters, suppliers, employees, contractors, regulators and the general public should have a prominent role. To increase acceptance for local pre-processing facilities and cement plants, conducting transparent emissions monitoring and making emissions values accessible to stakeholders can be useful.

3.2.4 Environmental Impact of AFR Use on Cement Products

Some metals (e.g. Hg, Tl, Cd, Sb, As, Pb, Cr) are called pollutants because they can affect health if taken up by living organisms in excessive quantities. As such metals are present in all input materials, conventional and alternative, they will also be present in the products cement, concrete and mortar.

The metal content of cement produced without AFR varies significantly depending on the geographical and/or geological origin of the raw materials and fuels used. Comprehensive investigations have shown that on a statistical basis, AFR use has only a marginal influence on the metals content of clinker and cement. The only exception is Zn levels that are increased by the use of tires. Of course, a statistical basis is not the same as the result of product monitoring, and so for this reason a baseline analysis of the metals content of the clinker and cement should be established prior to the introduction of AFR.

The final products cement, concrete and mortar act as a *"multi barrier"* system against the release of metals due to the:

- incorporation of metals in the crystal structure of clinker
- incorporation of metals in the hydration product of cement
- formation of insoluble minerals
- encapsulation of metals in the dense structure of concrete.

Assessments of the environmental behaviour of cement and concrete are typically based on the *leaching characteristics* of heavy metals to water and soil. Various exposure scenarios should be considered:

- Exposure of mortar and concrete structures in direct contact with groundwater ("primary" applications).
- Exposure of mortar or concrete in direct contact with drinking water in distribution (concrete pipes) or storage systems (concrete tanks); ("service life" applications).
- Reuse of demolished concrete in recycled aggregates, road constructions, dam fillings etc. ("secondary" or "recycling" applications).
- Disposal of demolished concrete in landfills ("end-of-life" applications).

Leaching of trace elements from concrete within the environmentally relevant pH values is a diffusion-controlled (i.e. extremely slow) process. But not all metals share the same principal leaching characteristics. *The main results of many leaching studies* done to assess the environmental impacts of heavy metals embedded in concrete are as follows:

- The leached amounts of trace elements from monolithic concrete ("service life" and "recycling" applications) are below or close to the detection limits of the most sensitive analytical methods.
- No significant differences in trace element leaching behavior have been observed between cements and concretes produced with or without AFR.
- The exception is in relation to chromium, aluminum and barium. Leachate concentrations of these three metals may, under certain test conditions, approach limits in drinking water standards.
- In particular hexavalent chromium in cement is water-soluble and may be leached from concrete at higher rates than other metals; therefore chromium inputs to cement and concrete should be limited as far as possible .
- Laboratory tests and field studies have demonstrated that applicable limit values (e.g. groundwater or drinking water standards) are not exceeded as long as the concrete structure remains intact ("primary" or "service life" applications).
- Certain other metals such as arsenic, chromium, vanadium, antimony, or molybdenum (so-called "oxyanions") may have a more mobile leaching behavior, especially when the mortar or concrete structure is destroyed by crushing ("recycling" and "end-of-life" applications).

It is not clear how to regulate the trace element content of cements, nor if their leaching behaviour is environmentally significant; and therefore if the user has specific needs for limitation of trace elements.

For different, real-life concrete and mortar exposure scenarios, different leaching tests and assessment procedures exist. Standardized test procedures have been developed mainly for drinking water applications. There remains a need for harmonized and standardized test procedures based on the exposure scenarios outlined above.

3.3 Operational Aspects

Principle 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) remain unchanged.
Requirement 6	**Suitability of waste/AFR shall be ensured so that it can be accepted for pre- or co-processing.** • Newly identified waste and AFR sources shall be subject to a pre-acceptance (source qualification) procedure prior to considering them for pre- or co-processing. • Pre- and co-processing shall not prevent the development of local and global recycling systems, and pre-processors shall divert recyclable materials to recycling where possible. • Traceability shall be ensured at the pre- and co-processing facility from reception up to final treatment. • Service level agreements between waste generators and pre-processing facilities as well as between cement plants and pre-processing facilities shall include quality specifications. • Waste categories unsuitable for pre-processing or AFR not meeting the quality specifications for co-processing shall be refused.
Requirement 7	**Transport, storage, treatment and handling shall be regulated and monitored** • Waste and AFR transportation, storage, treatment and handling shall comply with regulatory requirements. • Adequate procedures, equipment and infrastructure for transport, storage, treatment and handling of wastes and AFR shall be provided and maintained regularly according to the nature of the materials. • Waste and AFR treatment and handling systems shall be designed to minimize fugitive dust, to prevent spills, to mitigate fire and explosion risks and to avoid release of toxic or harmful vapors.
Requirement 8	**Standard operating procedures shall be clearly defined and known by operators** • AFR shall be fed to the kiln system only at appropriate feeding points depending on the AFR characteristics. • AFR feeding shall be avoided during kiln start up and shut down. • The technical conditions of the plant that influence emissions, product quality, and capacity shall be carefully controlled and monitored.
Requirement 9	**A quality control system shall be implemented** • Documented quality control plans shall be developed and implemented at each pre- and co-processing site. • Procedures, adequate equipment and trained personnel for the quality control shall be provided. • Appropriate protocols in case of non-compliance with defined specifications shall be implemented.

3.3.1 Transport, Storage, Treatment and Handling

Transport, storage, treatment and handling of waste and AFR – especially those with hazardous characteristics – should be subject to detailed regulations and legal requirements. The local, national and international (e.g. Basel Convention) regulations and requirements must be followed and the following good practices and commitments should be adopted.

Only authorized companies should be selected to transport waste and AFR to pre- and co-processing sites. Owners and operators of transport equipment shall:

- Provide evidence of proper maintenance of their equipment
- Employ only trained operators
- Comply with all relevant regulations and legal requirements in accordance with the nature of the transported materials
- Strictly respect requirements and procedures of the pre- and co-processing site when on their property
- For movement of AFR on- and off-site, select and contract only companies authorized to handle, transport and store waste and other similar materials to AFR.

The pre- or co-processing site should inform transport owners and operators about applicable requirements and procedures inside their property, and request the waste transporter to provide evidence about appropriate training of operators.

Internal transport, storage and handling of wastes and AFR shall be done in a manner to prevent spills as well as groundwater and soil contamination, to minimize the risk of fire or explosion, to control fugitive dust emissions and to contain volatile components, odors and noise. The pre- and co-processing site shall follow all industrial permitting procedures and:

- Develop requirements and procedures for unloading, storage and handling of waste and AFR
- Provide sufficient storage capacity and adequate handling installations
- Implement detailed spill and emergency response plans
- Implement adequate fugitive dust controls during internal transport, unloading, storage and handling of waste and AFR
- Control wind erosion/littering and water runoff from stockpiles
- Apply fire and explosion-safe design for all installations in accordance with the nature of the materials
- Provide adequate installations and equipment for suppression, removal or destruction of volatile gaseous components
- Ensure adequate use of personal protective equipment and training for on-site workers.

3.3.2 Kiln Operating Procedures

The general principles of good kiln operational control using conventional fuels and raw materials should be applied also during co-processing. In particular, all relevant process parameters should be measured, recorded, and evaluated continuously.

Kiln operators should be trained accordingly, with special focus on requirements related to the use of AFR. For start-up, shut-down, or upset conditions of the kiln, AFR use should be excluded and written operating procedures on how to stop AFR feeding during these conditions should be available and known to the kiln operators.

3.3.3 Chlorine Management

The impact of AFR on the total input of volatile elements such as chlorine, sulfur, or alkalis should be assessed carefully prior to AFR acceptance, as they may cause operational problems in a kiln. Specific acceptance criteria for these components should be defined individually by the site based on the specific raw material and fuel situation as well as kiln process type.

In cases of excessive inputs of chlorine with feed materials, cement kilns develop operational problems due to increased stickiness of the processed materials and associated buildup formation. Such operational issues are solved by extracting filter dust during direct operation or extracting part of the chlorine-enriched kiln gases from the kiln riser duct. The resulting intermediate products are called *cement kiln dust* (CKD) or *bypass dust* (BPD).

In some cases, particularly in the US, the market requires low-alkali cements. Alkali volatilization is enhanced by chlorine addition. Alkali and chlorine are then removed with a gas bypass system generating BPD. If alkali removal is done in long wet or long dry kilns then a different type of dust, called *cement kiln dust* (CKD, moderate enrichment levels) is produced.

In many countries CKD and BPD can be added to cements (if local cement standards allow).
However, in some cases it cannot be completely reused and thus landfilling might be required.

- If landfilling cannot be avoided, it should be done according to the rules of controlled landfilling.
- BPD and CKD should be compacted to prevent wind erosion, and the exposed face should be minimized.
- Effluents should be collected and treated before release.

3.3.4 Quality Control and Assurance

Pre-qualification
The potential use of any waste at a pre-processing facility or AFR at a cement plant should be subject to a detailed waste/AFR pre-qualification process consisting of the following steps:

- Identification of the customer (waste generator, waste management company) with candidate waste material (candidate source).
- Assessment of recyclability: is this waste stream currently or potentially recyclable, and will its use as AFR compete with any re-use, recycling, or materials recovery operations that represent a higher level of priority in the hierarchy?
- Evaluation of existing information, such as
  - business activity or process type of waste generation
  - intermediate storage or treatment of the waste
  - physical and chemical characteristics of the waste
  - health and safety data and hazards classification (material safety data sheet if available)
  - existing stock volumes and expected delivery rates
  - transport conditions (waste codes, transport codes, packaging, transport mode, legal requirements)
  - the way the waste is currently permitted, transported, and managed
  - violations or outstanding legal, or financial obligations that might affect a future user.
- Full-scale testing of a representative waste sample (source qualification analysis) including at least all chemical and physical characteristics listed in the operational permit and in the plant specifications, and comparison against given specifications.
- Creation of a Waste/AFR Qualification Master File of the candidate waste (*Annex 13*).
- In case of acceptance of candidate waste: contract and arrangement for waste deliveries, including agreed waste characteristics and acceptance criteria.
- In case of rejection, communicate criteria for non-acceptance to the customer.

Acceptance
Acceptance in routine operations should be controlled for each individual shipment to:

- Ensure compliance with internal H&S requirements (employee protection)
- Verify that delivered materials meet permit and plant specifications
- Take decisions for waste shipment acceptance or rejection
- Keep records for (potential) future requests, inquiries or allegations.

The full acceptance control has an administrative and an analytical part. The administrative verification includes:

- Inspection of accompanying documents (type and quantity of waste, waste code, origin of waste, carrier, date of delivery, transport code etc.)
- Inspection of waste certificate (physical and chemical data, H&S data etc.).

The analytical verification includes:

- Weighing of truck/load
- Visual inspection
- Sampling (representative sample)
- Tests/analyses (rapid/fingerprint tests)
- Comparison of the Shipment Control File against Qualification Master File.

The detailed control plan depends on the origin and nature of the waste or AFR and contains specifications on identification codes, responsibilities, sampling location and frequency, type of analytical tests, test frequency, and permit requirements. Documented work procedures for sampling, analytical tests, sample storage, laboratory equipment management (calibration, maintenance etc.), administrative procedures and validation of results should be available and communicated to the service personnel.

Acceptance criteria should be defined and updated on a regular basis in accordance with local regulation. Written protocols and instructions should be available detailing measures in case of non-compliance with given specifications or regulations. Suppliers of the waste or AFR must be informed about non-compliant deliveries.

Adequate laboratory design, infrastructure, sampling and test equipment should be provided and maintained to enable all required analytical tests corresponding to the waste/AFR types and control plan. Test samples and test results should be stored or filed for a defined period of time. Inter-laboratory tests should be carried out periodically in order to verify and improve the analytical performance of the laboratory.

Quality control personnel should be adequately trained according to the specific needs and to the nature of the wastes or AFR. Documented training plans and training records are to be developed and kept for reference.

AFR Quality Control
If wastes are pre-processed into AFR, a regular product control is required at the pre-processing facility to:

- Meet the permit and operational specifications of the cement plant
- Assure a constant quality of the AF or raw material for stable kiln operation and adequate product quality
- Assure employee's health and safety during handling and storage
- Prevent environmental risks or hazards at the cement plant (emissions, effluents).

Each batch of AFR should be inspected and/or tested prior to being delivered to a cement plant. In addition, grab samples for process control purpose should be taken on a regular basis. The complete test program according to the AFR Quality Agreement should be carried out on a composite sample of daily production. If the controlled batch of the finished AFR is not in compliance with the specifications, it has to be re-processed (*see Annex 14*).

In an attempt to harmonize solid AFs a European Standard for Solid Recovered Fuel, has been developed. SRF is a fuel derived from non-hazardous waste produced in accordance with the requirements of the European standards for SRF, specifically in accordance with EN15359. The main aim of the standards is to support the cross-boundary trading of waste derived fuels within Europe.

Clinker and Cement Quality Control
The production of cement requires rigorous control of the chemistry of the main ingredients: CaO, SiO_2, Fe_2O_3, and Al_2O_3, as well as other minor constituents such as sulfites (SO_3^{2-}), K_2O, Na_2O, TiO_2 and phosphorous pentoxide (P_2O_5). The mineral content of AFR may change the characteristics of the clinker. The raw material mix composition should be adjusted accordingly to maintain the desired product quality.

3.4 Health and Safety Aspects

Principle IV	**Health & Safety Aspects (H&S)** • 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.
Requirement 10	**A Health & Safety management system shall be implemented at all sites** • Identifying risks and mitigating them shall be the basis of the H&S management system. • Documentation and information on H&S shall be shared with all employees and the basis for openness and transparency about health & safety measures. • Pre- and co-processing facilities shall be designed and built in a way to protect the H&S of workers, the community and the environment. • Proper location, good infrastructure and properly trained employees can all minimize risks.
Requirement 11	**Emergency response plans shall be implemented for each site** • Adequate emergency response plans shall be implemented for all pre- and co-processing sites. • An on-site emergency response group shall be available. • Emergency response drills shall be executed regularly, including neighboring public intervention organizations.

3.4.1 Risk Management and Design Safety

Pre- and co-processing should be conducted in a manner that creates a healthy and safe environment for all stakeholders – employees, contractors, communities and customers. H&S is a matter of visible leadership and personal accountability for all of the organization.

There is no such thing as zero risk, but risks can be properly managed. H&S should be based on a proper risk assessment and complete implementation of all preventive measures. A risk assessment is the examination of the probability and magnitude/impact of a potential event. Risk assessments should be performed by commercial staff, waste transporters, pre-processing facilities, cement plants and engineers involved in the design and selection of pre- and co-processing equipment, during:

- Initial design or modification of facilities and equipment
- Definition of waste and AFR acceptance criteria
- Determination of criteria for specific work permits (e.g. hot work, confined space)
- Development of industrial hygiene programs
- Determination of when and where personal protective equipment is necessary
- Development of emergency response plans.

Data obtained from risk assessments should be used to prioritize which items must be immediately addressed or put into the mid-term planning process. Identified risks and mitigation plans should be communicated to all stakeholders, including authorities.

Design safety is one of the easiest, yet often underestimated, aspects of ensuring H&S.
Risk assessments are part of the design safety process:

- ✓ Sites must have all operating permits
- ✓ Sites should be chosen to minimize risks to employees and surrounding communities
- ✓ Layout of the site should be designed for the anticipated volumes
- ✓ Well-maintained equipment should be used
- ✓ Designs must comply with international guidelines, codes and legal requirements (e.g. SEVESO/ Directive 2012/18/EU, ATEX, National Fire Protection Association, VDI, BREF etc.).

Design consequence analysis can help in the determination of additional safety measures such as layers of protection (e.g ex-proof doors, reinforced walls, redundant fire detection) for critical areas or equipment.

3.4.2 Health & Safety Management System

Having an H&S management system is essential for any pre- and co-processing operation. Information about decisions on H&S should be available to all employees, contractors and other concerned stakeholders. The purpose of an H&S management system is to:

- Strive for continuous improvement in H&S performance (e.g. ISO 45001[6])
- Audit and review (plan, do, check, act); management review, internal audits, external audits (e.g. OSHA VPP[7])
- Have in place proper documentation (e.g. material safety data sheets, hazardous work permits, training records, equipment inspection and maintenance records, permits, audit results, environmental and medical monitoring results)
- Have in place task descriptions including the required personal protective equipment
- Provide job and task specific H&S training for all employees and contractors
- Report of all incidents.

6 *https://www.iso.org/standard/63787.html*
7 *https://www.osha.gov/dcsp/vpp/all_about_vpp.html*

3.4.3 Emergency Response Plan

Each site should develop, implement and communicate a detailed emergency response plan to ensure effective and rapid response to any kind of emergency. The emergency response plan should contain:

- description of areas of potential spills, fires and explosions
- work instructions and procedures to be used in the event of an emergency
- provide training for all employees, subcontractors and visitors on the immediate emergency response procedures
- reporting and communication requirements in the event of an emergency.

The site management should ensure that the emergency response plan is in place and communicated to all employees, concerned authorities and other relevant stakeholders, such as communities.

Having an emergency response group on-site is essential to take first measures against an emergency impact:

- Each site should organize an emergency response group, equipped and instructed (e.g. firefighting, spill response).
- The tasks and the equipment depends on the size of the site, the risks on the site and the distance to the next public intervention organizations (fire brigade, chemical intervention group, medical corps).

The emergency intervention groups should be trained regularly, including drills involving the neighboring public intervention organizations.


HYSTER
HYSTER 2.5
WARNING
KEEP 2 METERS AWAY


procycle

3.5 Social Aspects: Inclusivity and Stakeholder Engagement

Principle V	**Inclusivity and 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.
Requirement 12	**Mutual benefit of involved stakeholders shall be achieved** • Stakeholders in the existing local waste management value chain, including informal waste workers, shall be consulted and considered for collaborations. • Cement plants, including grinding stations and pre-processing stations should have at least one Community Advisory Panel in place at plant level. • Integration into the local value chain requires baseline and regular re-assessment also of social dimension focussing on problems, needs, and potential benefits.
Requirement 13	**Openness and transparency are the guiding principles in communication and engagement with all stakeholders** • Provide relevant information proactively to allow all stakeholders to understand the purpose of co-processing, the context, the function of parties involved and decision-making procedures. • Build credibility by being open, honest and consistent. Words should match with demonstrated facts and good performance. Gaps between what you say and what you currently do should be avoided. • Cultivate stakeholder dialogue based on mutual respect and trust. Participants in stakeholder engagement activities should be able to express their views without fear of restriction. • Different cultural environments should be taken into consideration. • Ensure continuity in communication; once you start, never stop.

3.5.1 Mutual Benefit and Inclusive Decision Making

In line with principles of ISWM, the changes to the solid waste system related to the introduction of pre- and co-processing must create mutual benefits to involved stakeholders in real time in the specific location where they are implemented. To achieve mutual benefits on a project level, the ownership of the project should also be shared and the initial preferences of the parties involved may need to undergo some shifting. This is because other key stakeholders, specifically the solid waste system institutions and the recycling/value chain enterprises (including informal recyclers), will need to bring their own priorities and considerations to the table. This process is likely to never be "finished" during the life of the co-processing operations, as economic, social, technical and political shifts are probable. The inclusivity and effectiveness of applied strategies will require continuous communication and evaluation especially when working with informal waste workers.

These mutual benefits must be clear to all stakeholders and it helps if these are measurable and capable of being documented and monitored, which can form part of the social and environmental impact assessment.

Box 9: Inclusive Decision Making

Inclusive decision-making is based on two-way and transparent communication in decision-making processes. These Guidelines should be understood as raising questions and offering possibilities, rather than providing ready-made answers. Sample key questions that can be stimulating in local decision-making processes could include the following:

- *What is working and what is not working in the local waste service sector and local recycling value chains?*
- *What materials are being or could be extracted from the waste stream, but not currently being recycled, re-used, or downcycled and what is happening to them?*
- *Is it possible to stabilize the recycling market demand and relations as part of an intervention around pre-processing?*
- *Are there value chain actors looking for support, or who could assist in pre-processing currently non-recyclable materials?*

Photo:
Biomass farmer meeting India.

3.5.2 Communication and Engagement

Communication and stakeholder engagement are vital in gaining a social “license to operate” from the local community and other stakeholders for pre- and co-processing. Communication activities can build awareness, inform, and create a forum for dialogue with a large network of stakeholders: government agencies, elected representatives, local residents, waste generators, transporters, and employees.

A license to operate requires trust from all stakeholders. Such trust is not easily earned. It will only be established by:

- Showing that you have nothing to hide (TRANSPARENCY)
- Showing that you have total command of the subject (EXPERTISE) and
- Managing the activity on the basis of tried and trusted professional practices (EXPERIENCE).

Some stakeholders are convinced by the “win-win” possibilities of pre-and co-processing, while others are concerned about potential health or environmental impacts.

The waste management sector and cement industry can be a valuable and respected partner for communities in infrastructure improvements, emergency cases or social developments. These opportunities and advantages should be communicated in an open and unselfish manner.

Legislation, guidelines and policies address these issues on an operational and scientific level, but communication and engagement plays a crucial role in the public perception: it has a key role in creating and maintaining a relationship with various stakeholders and avoiding the spread of rumors in public opinion as well as internally.

Communication and engagement should be done in a systematic way. All relevant stakeholders and their needs and concerns should be taken into account to create a shared understanding. To be effective, communication should be planned as early as possible.

The approach below provides a basic framework for communication and engagement activities. For specific topics, such as media relations, stakeholder relations, or crisis communications, each organization needs to implement appropriate procedures and trainings adapted to existing organizational structures and available resources. If necessary, seek support and advice from specialized agencies or partner organizations.

Situation and Stakeholder Analysis
Understanding stakeholders’ perceptions, expectations and motivations is the basis for all communication and engagement activities. Public opinion surveys, interviews with decision makers and opinion leaders and analysis of media coverage are some of the instruments to be used to develop an understanding of how you and your activity are perceived. This analysis may also reveal stakeholder concerns that need to be addressed. Analyzing stakeholders’ positions also allows you to identify potential allies as well as potential opponents. Stakeholders are people, groups, or institutions that are affected, might be affected, or might feel affected by pre- or co-processing or related activities. They have an interest in the company and can influence its activities.

Table 4: Stakeholder classification according to different levels.

Levels	Key stakeholders	Engagement activities
Internal	Employees, community, authorities, local NGOs, informal waste pickers, local media, customers, subcontractors	• Meetings, Q&A sessions • Workshops • Training
National	National governments, NGOs, customers	Public affairs, stakeholder dialogues, memberships and partnerships
Regional	Regional governmental organizations, regional offices of international organizations	Advocacy activities
International	International governmental organizations (UN bodies), international NGOs, WBCSD	Public affairs, stakeholder dialogues, memberships and partnerships

The communications needs of the different stakeholders vary from one group to the other. The situation analysis helps to identify these needs and the appropriate opinion leaders (people, groups or organizations). Promote two-way exchange of information in order to understand and address legitimate concerns.

Special attention should be paid to internal communication: if employees are unconvinced and unable to find answers to their questions, it will be difficult to convince other stakeholders. Employees are ambassadors and should be able to provide confidence that pre- and co-processing activities are run in a professional and transparent way.

Objectives
The communication objectives need to be adapted to the local and/or national audiences, for example:

At site level:
- Ensure support of your employees
- Earn the trust of neighbors and relevant stakeholders such as local NGOs, local authorities, and informal waste pickers (if applicable), and obtain or maintain the "license to operate".

At national level:
- Promote understanding of pre-processing of waste and co-processing in the cement industry and raise awareness of its benefits
- Raise awareness of the importance of waste management in a controlled, environmentally sound manner
- Draw policy-makers' attention to the subject of waste management
- Support the development and enforcement of an appropriate regulatory framework
- Promote acceptance and support for internationally endorsed guidelines for pre-processing of waste and co-processing in the cement industry.

Roles and Responsibilities
It is important to clearly assign roles and responsibilities for communications. Within companies, it should be clear who is responsible for media relations, internal communications, relations with authorities and crisis communication.

Topics and Messages
Key topics and messages should be based on the information gathered in the previous steps: they should address the interests and concerns of the stakeholders. Key messages should answer the questions: what? why? how? They should be specific and backed up by facts.

The closer to the plant level, the more focus should be on “how” rather than “why”. Waste management is not a naturally well understood topic by most stakeholders. This is why the wording should be adapted to the target audience. Simple and understandable vocabulary should be used when addressing the general public, and more specific ones when addressing professional target audiences. Developing fact sheets on key issues and assembling a list of *frequently asked questions* (FAQ) provides a basis for communications with different audiences.

Engaging with stakeholders helps to prioritize issues, reduce conflicts, and to forge alliances. In return, companies should be willing to provide time and resources and commit to increased transparency.

Communication and Engagement Tools
As stakeholder engagement is fundamental to maintaining a license to operate, tools for engaging with stakeholders to manage and integrate their expectations are of particular importance. Communication and engagement tools should be chosen by anticipating how the targeted stakeholders can be reached most effectively.

Evaluation
Periodic evaluation of communications and stakeholder engagement activities provides information on their effectiveness. The evaluation can be conducted by media coverage, feedback from the community advisory panels or surveys. Based on the results of the evaluation, topics, messages, and tools are adapted to changing circumstances or to improve the effectiveness of communication.

Table 5: An Overview of communication and engagement tools.

	Information sharing	Participation, consultation and coordination	Collaboration and partnerships
Internal	• Newsletter • Bulletin board • Intranet • Infographics • Videos • Internal briefing documents • Standard presentations • FAQ fact sheets • Websites • Case studies	• Meetings, Q&A sessions • Workshops • Training	
External	• Internet • Social Media • Reports, various types of publications, brochures • Advertising and sponsoring • Infographics • Videos • Press information (media release, press conference, site visits) • Fact sheets • Standard presentations • FAQs • Case studies	• Meetings • Conferences • Stakeholder dialogues • Events (open days, site visits) • Opinion/image surveys • Focus groups: research tool of small group discussions, • Community advisory panels – a key for co-processing: regular ongoing meetings with cross-section of stakeholder interests on diverse topics/issues • Community involvement: Addressing real needs and contributing to the development of host communities. Being a good neighbor entails working with stakeholders to help improve their quality of life	• Partnership projects: pooling resources (e.g. business, community, NGOs, government) to achieve a common social or environmental goal. • Cooperation with informal waste pickers (association, capacity development, etc.)

Case Study 6: Increasing Awareness on Recycling in Colombia

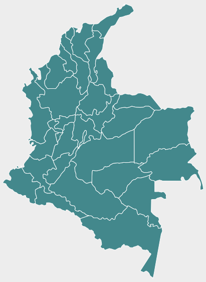


Photo: Recycling and co-processing campaign in Boyacá, Colombia.

Geocycle (Colombia), at the time still operating as Eco Procesamiento, made a campaign entitled campaña 'Reciclando y Coprocesado el ambiente estamos cuidando', ('by duly recycling and co-processing waste the environment is taken care of') as part of the promotion of new alternatives to safely manage waste in Colombia. Respecting the waste hierarchy and promoting recycling, as well as providing information on co-processing in the cement kiln and its technical advantages were strategic items of the campaign.

The campaign was based on an environmental education initiative, which encouraged a social movement involving several municipalities in Boyacá. Activities were carried out to strengthen the commitment of people at different levels in the waste value chain. Households, schools and other private and public institutions were targeted, and all agreed to change their habits and become part of this positive initiative. The initiative had three main components:

1. Set up and formalization of recyclers, driving a recycling culture.
2. Environmental training process development aimed at encouraging a culture of household waste separation at the source.
3. Development of the campaign; definition of sourcing points, collection routes and final waste treatment options.

Five municipalities of Boyacá including Tibasosa, Firavitoba, Corrales, Busbanzá and JAC Nobsa-Nazareth joined the initiative that benefitted around 18,000 people, recognized the work of those in the business of recycling, created formal jobs for these segments of the population and raised the awareness of recycling and co-processing. The campaign raised environmental awareness in the community through an educational and social process that drives changes, transforms mindsets and encourages a culture of waste separation at the source.

Education becomes the platform that supports the campaign from which a social movement is created that involves the whole community, and that reinforces the commitment to waste segregation and recycling at the source. Households, schools and private and public institutions have to be committed to changing habits and being part of the change.

3.5.3 A Key Value Chain Actor: Working with the Informal Sector

Informal recyclers and waste pickers are part of the waste management landscape in almost every developing country. Many studies have shown that the informal waste sector can significantly support municipal waste management, but can also negatively affect local waste management systems if not integrated effectively. In many low- and middle-income countries, they can represent as much as 1% of the total population and are usually active at the bottom level of the value chain. Their engagement can contribute to recycling rates of 20 to 30% in low-income countries (Wilson et al., 2012), and saves local authorities around 20% of what they would otherwise need to spend on waste management (Scheinberg, et al., 2010).

Most informal recycler's income derives from selling into secondary material markets in which prices are volatile and access to markets is given through intermediaries, who often buy below market prices so that they may also make money off the sale. Informal waste workers face many serious problems, such as poor working and living conditions, especially when they work (and live) on or near landfills or open dumpsites. Workers usually work without protective clothing or equipment, resulting in direct contact with waste and numerous occupational health risks. In many cases, vulnerable groups such as children, women, and the elderly are the most exposed to these risks.

In relation to pre- and co-processing, the discussion of what happens to the informal sector remains relatively new. Respecting the consensus that informal recyclers cannot be ignored while attempting to improve waste and resource management, this section elaborates on potential conflicts and opportunities in integrating informal workers in the landscape of pre- and co-processing (Velis et al., 2012). Some generic principles and guidance for working with and integrating informal waste workers in the formal waste management system is given in *Annex 16*.

A number of synergies for cooperation with the informal sector exist mainly in the field of pre-processing of waste, rather than co-processing, which happens at the cement plants 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. Their work means that they are already in the business of handling or rejecting a range of recyclables, as they know the materials, the markets, and the weaknesses in the recycling value chain. Thus, cooperation can save time, increase fuel quality, and avoid conflicts that might come about if they are not consulted. Informal recyclers know the local waste markets very well, and can provide information on what can or cannot be sold in their specific location. Often they also know why particular materials have no markets and would qualify for AFR.
- Informal recyclers are at risk when the waste system is modernized and have an interest in being included and in finding new roles. Studies indicate that 20% of active waste pickers might choose supported exit of informality (GIZ, 2018). These are usually older people who are looking for a "retirement" activity because they are physically unable to continue with the heavy physical work, or younger people who are not yet skilled at marketing materials. Giving them training and employment could be an option to exit informality into regular employment.
- Collaboration strengthens the "social license" of an operator as the quality of life of communities around pre- and co-processing operations are improved. This helps to establish and deepen relations, ultimately adding value to business without receiving or expecting a business or financial advantage in return.

However, there is some potential for conflicts between waste pickers and pre-processors:

- Competition for materials – for example, if a co-processor creates a demand for informally traded materials that have both a high value as components of AFR (e.g. tires) and recycling value (e.g. shoes in Egypt). In such cases the principles of the waste hierarchy should prevent materials entering co-processing.
- Meeting formal cooperation standards – informal waste workers may not be used to collaborate in contractual agreements and tend to have an entrepreneurship character. Often patience is required and waste pickers may be more easily engaged through waste associations, cooperatives, or NGOs working with the waste pickers to formalize these. Contractual relations in these instances are likely easier to develop with companies, or cooperatives employing ex-informal workers.
- On an operational level, practical solutions need to be established to formalize a cooperation avoiding reputational risks and complying with transparency, anti-bribery and anti-corruption standards (no cash payments), labor rights (including child work) and H&S requirements. However, opportunities of digital payments (mobile money) are now enabling easier ways to track and monitor cooperations directly with informal workers.

Potential activities with informal recyclers in the field of pre- and co-processing

- Waste pickers may remove marketable recyclables from mixed waste before it is pre-processed, or play a role in the pre-processing activity itself. With support through training, informal workers can achieve a high quality of AFR for the cement plant. Sorting can take place at landfills and dumpsites, enabling recovery of materials which would otherwise have been disposed of, at the same time improving the income and outlook of informal waste workers.
- Often non-recyclable fractions which would be suitable for processing into AFR represent a cost burden to informal waste pickers and they are looking for avenues to dispose of this (either at own cost, or through sending to local dumpsites or poor treatment). Cement plants can be suitable off-takers for this waste fraction.
- Public private partnerships with local pre-processing centres and municipalities may lead the way for improved cooperation with the local municipality and informal workers, setting up assured material streams and providing better incomes to the local value chain (*see Egypt case study below*).

Case Study 7: Promoting the use of *Refuse Derived Fuel* (RDF) through Public Private Partnerships

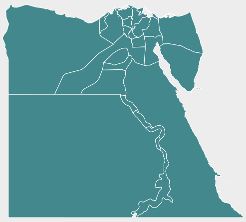
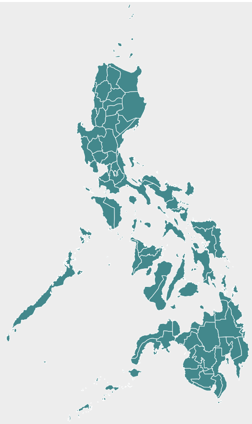


Photo: Sorting station in Qalyubeya, Egypt.

In Cairo/Egypt, there is a long-standing tradition of Zabaleen (informal waste collectors) recovering resources out of waste. Inside the Zabaleen living and working areas in Khosoos in Qalyubeya residual waste accumulation became a problem. More than 40 tons of waste daily, in the form of rejects with high calorific value, lay on the streets after all sorting activities were finalized. This represented an economic burden on the Zabaleen to dispose of the waste elsewhere. Additionally, this waste was mostly disposed of on main roads and in the vicinity of public buildings and schools. The problem posed a threat to the public health of Zabaleen society and contributed to the waste accumulation problem at large.

With funding from BMZ and the Bill and Melinda Gates Foundation, GIZ and Lafarge carried out a public private partnership with the Zabaleen to find ways to use this non-recyclable waste in co-processing facilities. Institutional and technical support was given to one of the formalized Zabaleen companies (El-Ekwa private company) in establishing an entity to collect, sort and sell RDF material. The company eventually succeeded in forging a contractual agreement with Lafarge Egypt to supply it with RDF material (up to 25 tons per day for a contract duration of 5 years). The company went through a learning process to fully understand the quality requirements of Lafarge. Over time and with continuous support from Lafarge the company was able to provide material of high quality and consequently increase its revenues. This initiative demonstrated that extracting the energy rich fraction from waste does not necessarily have to be in conflict with promoting recycling as the company was only providing material for co-processing after sorting the recyclable material which was sold in recycling markets. The cooperation led to new business opportunities among the informal worker community and empowering them. Around 40 new direct job opportunities for Zabaleen were created and workers trained in accordance to Geocycle standards. At the same time it enabled elimination of 40 tons of daily waste rejects, which were generated inside the Zabaleen communities areas after all sorting processes were finalized.

Case Study 8: Sorting station with waste pickers at a landfill in the Philippines



In Iloilo City in the Philippines, a cooperation between GIZ, Holcim and the local municipality worked with informal waste workers to sort recyclables and inert fractions using a mechanized sorting plant at the dumpsite, before sending the residual fraction as alternative fuel and raw material (AFR) to the local Lafarge-Holcim plant (Paul et al., 2012). During a 3 month test at the mechanized waste sorting plant it was demonstrated that up to 30 % of the processed waste at the sorting facility were light-density packages that could not be reused or recycled locally but would be suited as AFR for co-processing. The test also showed that a recovery of up to 30 tons per week is possible by working in 2 shifts, each with 15 workers (Paul et al., 2010).

Co-operating with informal recyclers to achieve maximum diversion of recyclables from disposal can be a win-win. In the Philippines case, local government received support to reduce waste disposal and to organize local waste pickers, the latter benefited from enhanced working conditions, additional income through more efficient material recovery, a strengthened position as a waste workers association and various trainings and organizational support. Holcim on the other hand gained valuable experience in testing the recovery of AFR in a municipal context, together with relevant processes related to monitoring of AFR quality, and the design of storage and bailing systems to protect bailed AFR against the regular occurring heavy rains. Based on the promising test outcomes, the local government, Holcim and the waste workers association agreed to formalize their working relation within a Memorandum of Agreement that clarified rules, processes, functions and duties of the jointly performed AFR recovery. However, the higher costs for handling the waste in this way led to discontinuation once the project financing ended – showing the need for robust financing concepts behind projects to make them sustainable in the long term.

Photo:
Female workers at Material Recovery Facility in Iloilo City.

3.6 Economic and Financial Aspects

Principle VI	**Economic and Financial** • 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.
Requirement 14	**Pre- and Co-processing projects should be based on a financially sustainable business model** • A common understanding about the financial implications of pre- and co-processing shall be developed since transforming waste to suitable AFR requires investment and operating costs. • The polluter-pays principle should be applied using a mix of realistic financing instruments (tariffs, gate fee, incentives and EPR schemes). • The financing framework of waste management shall be guided by the waste management hierarchy, incentivising more environmentally friendly options. • Financing needs to be agreed upon within a specified and sufficient contract period considering a long term perspective allowing for a fair depreciation period and return of investments.

3.6.1 The Importance of Robust Financing

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 (GIZ, 2017).

Figure 20 below shows the different costs and revenues faced by different actors along the value chain from waste management activities at the municipal level through to pre-processing and co-processing at the cement plant. Revenues come from sorting out of recyclables and from savings during co-processing at the cement plant by substituting more expensive primary fuels and raw materials. Costs throughout the value chain occur during collection, sorting, transport, pre-processing, co-processing, as well as the capital and operational expenditures on equipment and facilities.

In an ideal case the savings from fossil fuels substitution alone would offset the costs of the other steps in the chain, however, this is rarely the case, meaning that a waste management fee must often be paid for by the waste generator. Where waste has already been pre-processed to a high quality AFR, cement plants may pay for it where it can directly substitute their primary fuel and raw materials needed in the cement kiln.

Organizing financing along the value chain is not always straightforward. Decision makers in developing countries often expect to earn money by selling their waste to cement plants, while the cement plants often expect to be paid for using AFR, which leads to unnecessary difficulties in communication. 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, rather than an occasional off-taker. At the same time it is important to factor in operation and maintenance costs, as investment projects in the waste sector fail too often due to missing budget for this.

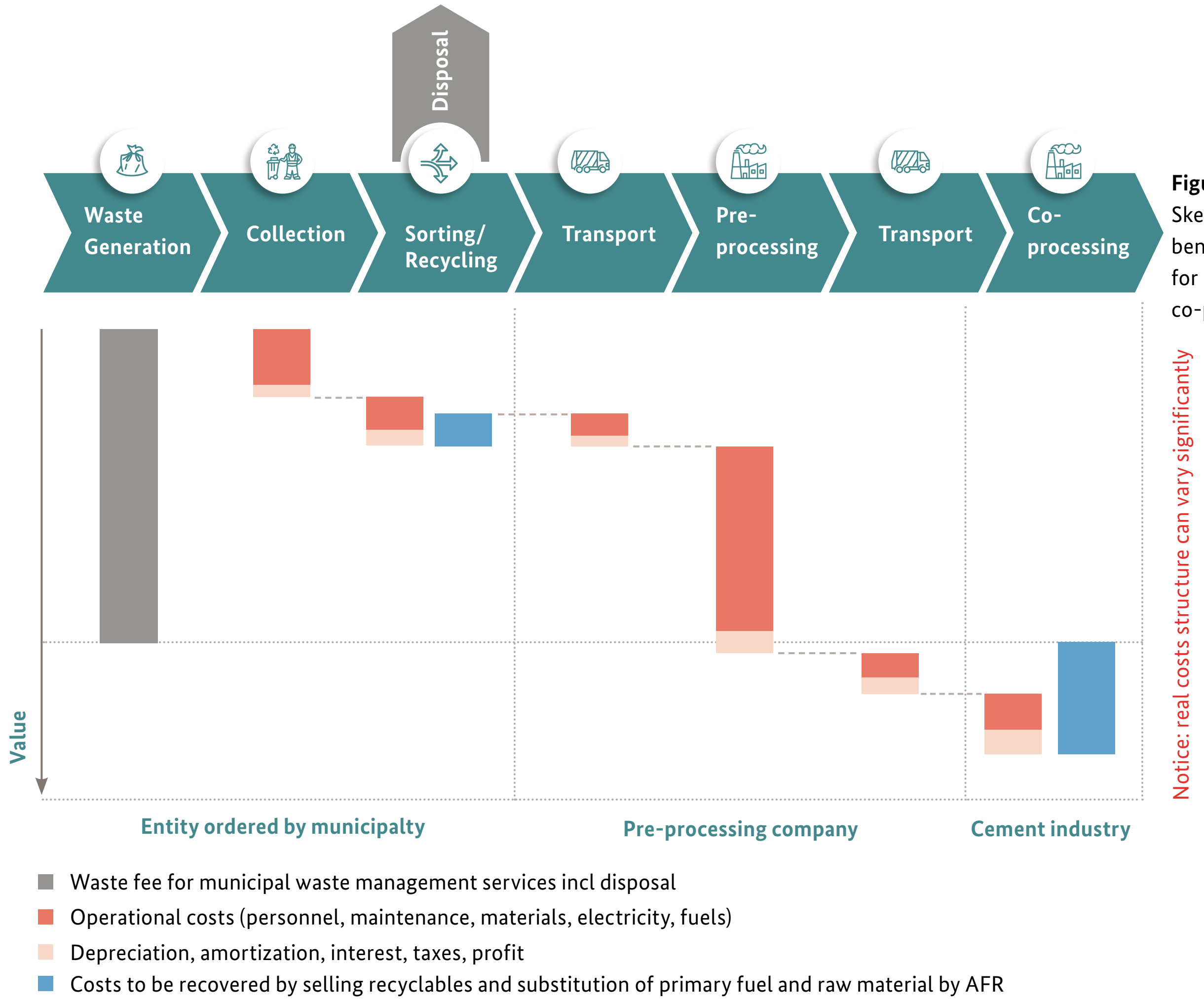


Figure 20: Sketch of a cost benefit waterfall for pre- and co-processing.

Local authorities in low and middle income countries are unlikely to agree to pay a disposal fee that is higher than the cost of landfill or controlled dumpsite. In these countries, it is rare that the disposal fee is higher than US$10 – or maximum US $25 – per ton. Where payment for waste disposal services is not established or below US$10 per ton, it will be difficult for municipalities to find revenues to pay cement producers for handling MSW. Political authorities may in fact expect the cement producer to pay for the waste, thinking that if it can be burned in the kiln it must have some value. This is problematic, as cement producers look at AFR as a way of controlling costs. If the cement producer is willing to pay, it is not likely that this payment will do more than cover the operational cost of pre-processing, which may mean paying the pre-processer and not necessarily the municipality.

There is little a cement producer can do to change this at the local authority or national finance ministry. However, it helps when the cement producer can transparently and simply communicate the amortised capital cost, operations and maintenance costs, and understand whether AFR use creates reliable and realistic savings on primary fuel and raw material cost.

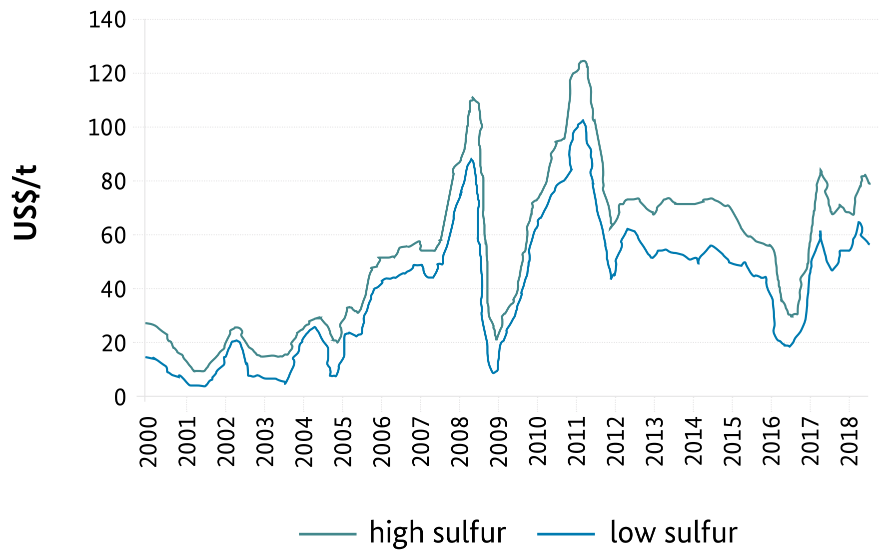
The second step is to consider the costs of pre-processing, because if paying for pre-processing (or buying AFR at a price that includes the cost of pre-processing) is not an option for the cement producer, co-processing will not be considered a feasible option for any of the parties under the current financial conditions in most low- or middle-income countries.

3.6.2 Business Case

A viable business case for pre- and co-processing is heavily dependent on the fees of alternative treatment options for the waste streams under consideration as well as the market price for primary fuels and raw materials. In order to be financially attractive for the cement industry, the expected long-term reduced fuel and raw material costs must result in an increased competitiveness taking into account the associated risks. Further factors such as CO_2 reduction targets and carbon pricing, long-term secure access to resources and public reputation influences investment decisions positively, but are not yet a decisive factor.

For the waste generating industries and municipalities, pre- and co-processing can be an attractive option if no other environmentally, socially and financially sound alternative is available. For municipalities with tight budget situations, even low additional costs might be a challenge. In recent years the drop in fossil fuel prices has significantly impacted the financial attractiveness of co-processing, demonstrated by the petcoke price development in *Figure 21.*

Figure 21: Petcoke price development (Source: Own graph, data from PACE Petcoke Index United States Gulf Coast, Free on Board – excludfing freight).



Annex 4 gives an example of a generic business case on pre-processing of MSW and subsequent co-processing of AFR in a state of the art cement kiln. The investments in a pre- processing facility and kiln feeding system add up to 14 million US$. A chlorine bypass, which already exists in the case would increase investments by another US$ 5 million. The substitution of 32% of petcoke by RDF reduces CO_2 emissions by about 66,000 tons CO_2 per year or 17%. The estimation considers transportation of petcoke and MSW, pre- and co-processing of AFR. GHG mitigation by avoided landfill gas emissions are not considered.

Based on this case, *the figure below* presents the minimal required gate fee depending on the anticipated future average petcoke price to be financially viable. In the example of a long-term petcoke commodity price of 115 US$/t, a gate fee of 20 US$/t presorted-MSW is required to make the implementation of a pre- and co-processing project without chlorine bypass financially viable. Consequently a gate fee (tipping fee) for landfilling should be higher than this price. These are only example numbers that can change significantly from country to country.

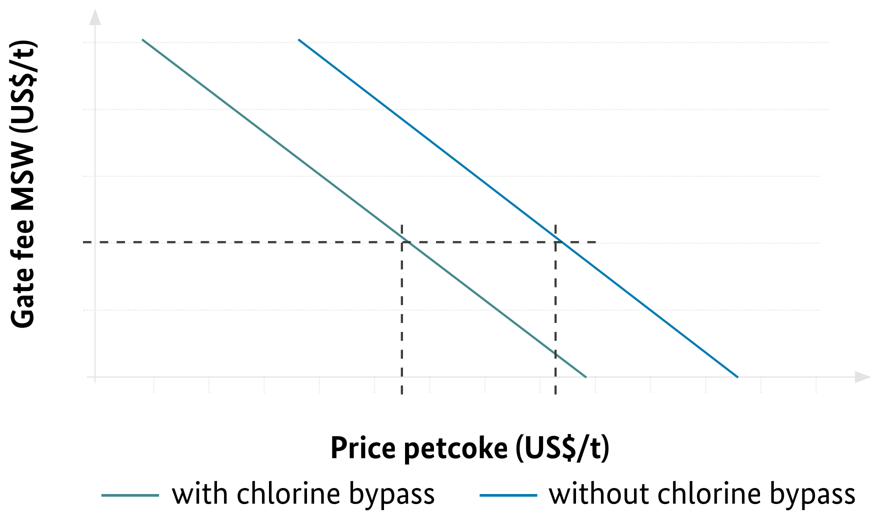


Figure 22: The gate fee for waste for cost-effectiveness of pre- and co-processing depends on the anticipated costs for primary fuel.

Investment (CAPEX) and Operating Cost (OPEX)
The level of required investments for pre- and co-processing depends on the treated waste streams and corresponding level of pre-processing needed, the used AFs and raw materials, and corresponding AFR storage, handling and dosing systems needed as well as upgrades needed by the cement kiln system itself (e.g. chlorine bypass) to enable co-processing of the desired AFR volumes without compromising cement plant output and product quality.

Waste	CAPEX	OPEX (transportation excl.)
Spent solvents	€5 million to €10 million	€10 to €20 per ton
Waste oil and industrial Oil	€1 million to €3 million	€5 to €10 per ton
Pre-processing used tires and rubber wastes	€1 million plus infrastructure costs	€15 to €40 per ton
Co-processing used tires and rubber wastes	€1 million to €3 million	€5 to €10 per ton
Pre-processing non-hazardous industrial waste	€5 million to €20 million	€5 to €40 per ton
Co-processing non-hazardous industrial waste	€1 million to €15 million	€5 to €20 per ton
Municipal solid waste	€5 million to €50 million	€10 to €40 per ton

Table 6: Example of CAPEX and OPEX for pre-and co-processing of different waste worldwide (based on IFC, 2017 and amended with own data).

3.7 Implementation of the Guidelines

Principle VII	**Implementation of the Guidelines** • Monitoring and auditing systems need to be in place to enable successful implementation. • Capacity building and training at all levels is essential.

These Guidelines recommend environmental, social, technical, financial and legal requirements. They shall not be regarded as a binding law. Their application enhances broad acceptance of pre-processing of waste materials and co-processing of AFR in cement plants. For the implementation of the proposed ambitious but realistic principles and requirements a stepwise approach is needed, depending on the existing framework conditions in the different countries.

The level of economic development, environmental consciousness, political priorities, good governance or cultural habits influence the dynamics and timeframe of the modernization of waste management in a country. 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 from one day to another, a gradual phasing-in is needed. The implementation speed is determined by the given political, social and legal circumstances and achievement of realistic milestones.

All actors involved must have at least a basic understanding of waste management and those who are directly involved in operational procedures, supervision and monitoring must have additionally specific knowledge on pre- and co-processing. Wherever such knowhow is missing, capacity building schemes shall be considered as the first step of the implementation. Training can be offered in line with the structure of these Guidelines.

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.

Case Study 9: From guidelines to implementation: Adopting and piloting national co-processing guidelines in the Philippines

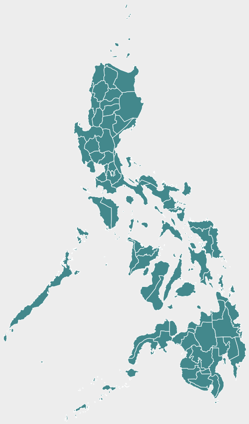


Photo: Community consultation at MRF in Iloilo City.

To support waste recovery in the Philippines, the national *Cement Manufacturers Association* (CeMAP) and the *Industrial Technology Development Institute* (ITDI) of the *Department of Science and Technology* (DOST) joined forces in 2005 with the support of *Deutsche Gesellschaft für Technische Zusammenarbeit* (GTZ), what is today *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ). The main objective of this alliance was firstly to develop a guideline on co-processing of Alternative Fuel and Raw materials in cement kilns, and secondly to legalize this recovery solution for suitable waste fractions from municipal solid waste.

Moving from general guidelines to an implementation framework was addressed by three main steps:

1. From 2006 – 2008 the cement association and government conducted stakeholder dialogue to determine relevant guidance for the Philippine context, facilitated by GTZ.
2. Based on this guidance, steps were taken to develop legal-backing, which was passed in 2010 by the Environmental Management Bureau.
3. Application of the guidance and legislation was tested in a pilot initiative with Holcim and GIZ in Iloilo City, which also integrated the informal sector.

For the country-specific guideline the 2006 GTZ-Holcim guidelines were used as a basis for discussions. Major challenges included motivating the cement producers in the Philippines to participate in the initiative as well as maintaining stakeholder commitment and acquiring necessary information, particularly since the cement producers have competitive roles and interests. At project start in 2006, nine different cement companies were operating 17 cement plants in the Philippines. Following a series of stakeholder meetings from 2006 – 2008, CeMAP finalized the publication of country-specific guidelines on co-processing of AFR in cement kilns in the Philippines.

During the project development it became clear that most municipalities were not aware of the role co-processing can play to increase material and energy recovery. To give the guideline legal backing, CeMAP and GTZ initiated a follow-up process to gain verification and adoption of the guidelines by the responsible authority of the Philippines, the *Environmental Management Bureau* (EMB) of the *Department of Environment and Natural Resources* (DENR). The main challenge here was to find an agreement on a definition that distinguishes co-processing from other waste-to-energy solutions, particularly since the legislation explicitly forbids waste incineration (Republic Act 9003, Section 3). This aspect was clarified with concerned non-governmental organizations. Finally EMB accepted co-processing as an option for MSW management in 2010 and released a related Department Administrative Order (DENR-DAO 2010-06).

3.7.1 Capacity Building

Pre- and co-processing presents challenges for the different actors involved in waste management and cement production. This includes operators of pre-processing facilities and cement plants, but also regulators and municipal bodies responsible for waste management and environmental protection. The pre-processing facility and cement plant operators need to understand and control all impacts that pre- and co-processing will have on the production process, on the environment, and on the H&S of the workers. Regulators should also understand all these aspects in order to fulfill their roles in controlling environmental and H&S impacts. Municipalities need to understand the relevance of an efficient waste management system and its costs. Both operators and regulators should understand the concerns of the public over possible negative effects of pre- and co-processing, and they should establish efficient communication processes in order to explain their activities and to avoid conflicts.

In some places the challenges are more complex. In most countries a basic form of environmental legislation exists, but often there is no effective enforcement because of lack of human capacity, awareness or resources. Most developing countries lack information on the methodology and evaluation of data from emissions monitoring. Reliable waste statistics are often non-existent, and documentation systems for tracing waste are not known. The lack of waste management plans does not allow for a financially and ecologically optimized treatment of waste. Thus, institutional setup and capacity building is required for the regulatory bodies, operators of pre-processing facilities and cement plants to ensure environmentally sound and efficient pre- and co-processing.

The content of this guideline shall contribute to empower the involved stakeholders to achieve the benefits of pre- and co-processing. But these Guidelines should not be understood as a “copy & paste” instruction for the implementation of pre- and co-processing in a country, each country has its own prerequisites and requirements. Capacity building supports the adaptation of the Guidelines to national needs and its implementation.

When national and local decision makers decide to integrate pre- and co-processing into waste management systems, the legal and institutional framework must be adapted, and those involved from both government and business need profound knowledge of the implications of the decision. A comprehensive capacity development program should be designed and agreed on with the relevant stakeholders. Such a program would need to cover legal, technical, social, environmental and financial aspects of waste management in general and pre- and co-processing in particular. Reliable and well-trained external auditors, service company personnel, and experts from the public and private sector working in the field of waste management and cement manufacturing are needed to make pre- and co-processing work. In order to ensure quality and to simplify the work of administrative bodies, the certification of transportation companies and pre-processing facility operators, of laboratories for quality control, as well as of individual experts, is most important.

Waste generators, informal waste pickers, transportation companies and pre-processing facility operators will be involved in handling and treatment of waste before its delivery to the cement plant. Efficiency requires the optimization of material flow, waste separation, safe handling of the materials already from the source to final treatment, and adequate installations for transportation and storage. Management and workers need to be trained accordingly. The permitting and supervising authorities must concentrate on their coordinating and enforcement functions, therefore they do not need to provide all relevant knowledge and experience but can rely on external expertise. However, the officers directly responsible for the permitting control and enforcement procedures should have a profound understanding of pre- and co-processing. Training might be required regarding:

- Formulation of waste management policies
- Collection, validation and interpretation of available waste data and statistics
- Integrated waste management planning including financial and economic aspects
- Authorization / permitting and controlling of pre- and co-processing plants
- Assessment of new waste streams for pre- and co-processing and source qualification
- Monitoring of operation and transportation (emission analysis and evaluation of data)
- H&S of workers during transportation, within pre-processing facilities and at cement plants
- Enforcement of national regulations and permissions
- Systematic communication with stakeholders and the public.

Pre-processing facility and cement plant operators on various organizational levels may need training in:

- Waste classification, control of waste and AFR quality
- Operation of facilities for pre- and co-processing according to external regulations and internal standards
- H&S
- Communications
- Monitoring of environmental (emission) aspects
- Auditing techniques and audit protocols
- Periodic certification of employees and subcontractors.

Training could be done through or in cooperation with bilateral and multilateral organizations (i.e. the national focal points of international conventions like Basel or Stockholm). Additional partners for training could be cement associations, specialized research institutes and universities (e.g. FHNW).

A training should be target group oriented. While decision and opinion makers (e.g. politicians, ministers, municipalities, NGOs) need an overall understanding of pre- and co-processing, environmental authorities and plant operators need a more in-depth training. With an adequate didactical concept, a long-term effect of capacity building should be ensured (e.g. workshop, training on the job, coaching).

Before planning initial trainings on pre- and co-processing the following questions should be answered:

- How advanced is the existing waste management system (e.g. efficient waste separation and collection system, recycling, controlled landfills)?
- What are the gaps (e.g. environmental framework appropriate for environmental sound pre- and co-processing)?
- Which stakeholders need capacity building (e.g. operational staff in authorities, informal sector, pre-processing facility or cement plant operators)?
- Which skills shall the participants have after capacity building (e.g. waste characteristics, emission monitoring, waste statistics, H&S inspection)?

ANNEXES

PART 4: Annexes

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Annex 2 – Examples list of waste material suited for pre- and co-processing

Table 7: Examples of waste suited as AF (incl. calorific value and CO_2 emission factors).

	Calorific value (GJ/t)[8 9]	Emission factor (kg CO_2/GJ)[10]	Share Biomass
waste oil	25 – 36	74	0
tyres	25.1 – 31.4	85	27%
plastics	21.0 – 41.9	75	0
solvents	20 – 36	74	0
impregnated saw dust	14 – 28	75	20 – 75%
dried sewage sludge	8 – 13	110	100%
wood, non impregnated saw dust	Approx. 16	110	100%
paper, cardboard	3 – 16	110	100%
animal meal	14 – 21.5	89	100%
agricultural waste	12 – 16	110	100%
RDF	11.6[11] 16.8[12]	45.9 61	50% 40%

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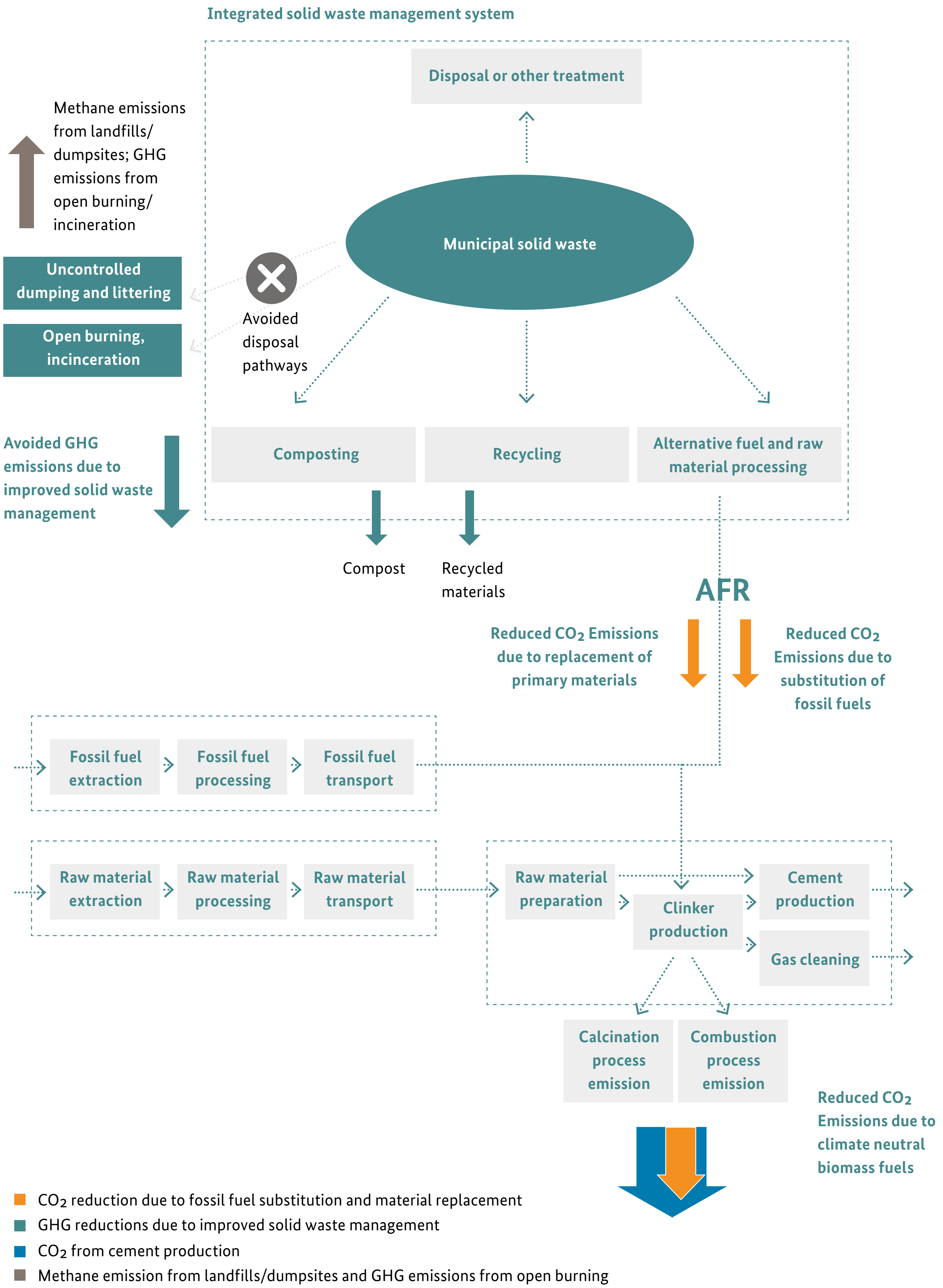
Table 8: Examples of waste suited as AR.

Waste	Useful compounds
Fly ash	Si-Al-Ca
Blast furnace slag	Fe
Silica fume	Si
Iron slag	Fe
Pyrite ash	Fe
Soil containing oil	Si-Al-Ca
Artificial gypsum (from flue-gas desulphurisation and phosphoric acid production)	S
CaF_2, Filter sludge	Ca-F
Red Mud	Fe
Sludge from drinking water treatment	Ca
Spent foundry sand	Fe

Annex 3 – GHG impact of pre- and co-processing



Annex 4 – Business case example pre- and co-processing of RDF

Here a generic business case is calculated for pre- and co-processing of RDF to offer a better understanding of economic and climate aspects of using waste as AFR in cement production. A state of the art cement plant which produces 1.2 million tons of clinker per year is taken as an example, with annual petcoke consumption of 180,000 tons and greenhouse emissions from burning petcoke to 390,000 tons of CO_2 (*Table 9 and Table 10*). The petcoke is imported from overseas and transported by rail to the cement plant. Increasing petcoke prices cut on profit margins and CO_2 reductions require actions (*Table 11*). In cooperation with an international organization, the management has implemented a co-processing project for RDF to sustain competitiveness, to mitigate GHG emissions and to improve waste management of the local municipality.

The landfill site receives 200'000 tons per year of mixed MSW. A waste picker cooperative sorts out all valuable recyclable such as metals, plastics, PET glass, cardboard etc., which is the source of their income. The international organization has funded a basic sorting and recycling facility, operated by the waste picker cooperative, consisting of a trommel screen for removal of organics, conveyor belt for the manual sorting work and a van for the transportation of the recyclables. The annual amount of sorting residues adds up to 120,000 tons. At a humidity of 50%, the caloric value of 10 GJ/t is too low for co-processing. The mechanical-biological pre-processing facility, operated by the cement plant is located in a distance of 80 km by road. The pre-processing operator is also responsible for the transport of the sorting residue from the sorting station to the pre-processing facility and additionally receives a gate fee from the municipality. At the pre-processing facility the sorting residue will be qualified, dried and shredded to obtain 80,000 tons of homogenous RDF at a humidity of 25% and a calorific value of 16 GJ/t. The RDF substitutes 32% of the petcoke in the cement plant (*Table 12*). The initial investment amounts up to 14 million US$ for the pre-processing facility (incl. planning and engineering) and kiln feeding system. A chlorine bypass already exists, if not, additional 5 million US$ are required (*Table 15 and Table 16*).

According to the investor rules, any project requires a payback of 5 years. The financial valuation has shown that the dynamic payback time of 5 years is achieved at current petcoke prices (114 US$ USGC Index) and a gate fee of 20 US$/t, which also can be financed in a long term perspective by the municipality. Furthermore the internal rate of return of 33.7% is higher than the weighted average capital costs of 8.5% for this type of project and country. (*Table 17*)

The CO_2 emission reduction of the project (excluding petcoke transportation) adds up to 67,500 t CO_2/year, which is 17% of the baseline (*Table 13 and Table 14*).

Production capacity kiln	1.46 million	t/year
Operation efficiency	82	%
Clinker production	1.2 million	t/year
Petcoke consumption baseline	117,647	t/year

Table 9: Baseline: assumption cement plant thermal energy consumption.

IPCC CO_2 emission factor petcoke	97.5	kg CO_2/ GJ
CO_2 thermal energy	390,000	t CO_2/year
CO_2 emission Baseline	395,279	t CO_2/year

Table 10 Baseline: CO_2 emissions from transportation and burning petcoke.

Costs petcoke	114	US$/t
Costs petcoke at burner (amount)	174	US$/t
Costs baseline	**20.4 million**	**US$/year**

Table 11: Baseline: cement plant petcoke costs.

Table 12 Project: Pre- and co-processing of RDF from MSW residues (sorted by waste pickers on a landfill site).

MSW amount wet (net calorific value 10 GJ/t, 50% moisture)	120,000	t/year
RDF Amount after drying (net calorific value 16 GJ/t)	80,000	t/year
RDF thermal energy	1.28 million	GJ/year
Thermal substitution rate	32%	
Petcoke substitution by RDF	37,647	t/year petcoke

Table 13 Project: CO_2 emissions of pre-and co-processing.

CO_2 emission pre-and co-processing	61,064	t CO_2/year

Table 14 Project: CO_2 emission reduction.

CO_2 emissions baseline	390,000	t CO_2/year
Reduced petcoke consumption	32	%
Reduction CO_2 emission of project (amount)	65,736	t CO_2/year
Reduction CO_2 emission of project (percentage)	17	%

Table 15 Project: *Operational Expenditure* (OPEX) of pre-and co-processing.

Gate fee at landfill for MSW residues (paid by municipality)	-20	t/MSW residue
Total cost of RDF after transport, pre-processing and feeding to kiln, incl. gate fee (amount)	**8**	**US$/t RDF**
Total RDF (energy)	**0.5**	**US$/GJ RDF**

Total investment (incl. chlorine bypass)	14 million	US$

Table 16 Project: *Capital Expenditure* (CAPEX) of pre-and co-processing.

Weighted Average Cost of Capital **(WACC)**	8.5	%
Project period	20	years

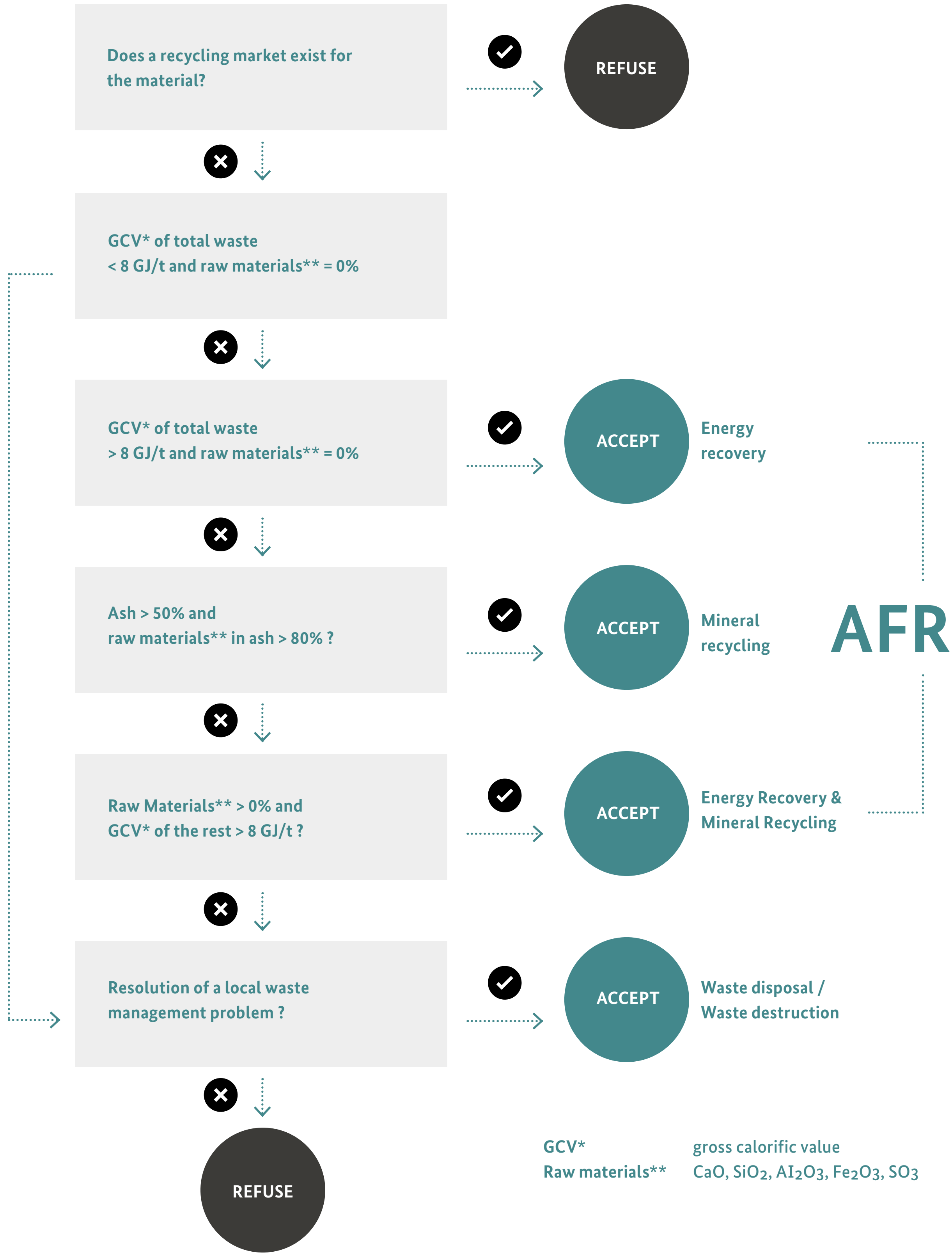
Table 17 Project: financial parameters.

Internal Rate of Return (IRR)	33.7	%
Net present value	27.228 million	US$

Table 18 Project: results financial valuation.

Annex 5 – Example of an accept-refuse chart (co-processing)

Accept or Refuse Flowchart for a Cement Plant Operator



GCV*	gross calorific value
Raw materials**	CaO, SiO_2, Al_2O_3, Fe_2O_3, SO_3

Annex 6 – Examples for limit values for waste and AFR

Table 19: Limit values for waste used in cement kilns in Austrian legislation, in guidelines from Nordrhein-Westfalen (Germany) and with French permits.

Substance	Austria[13]				Nordrhein-Westfalen[14]	France[15]
	AF in cement kilns with preheating and calciner		Wastes, which are not an AF		Waste as heating fuel▲	Input criteria for substances for suitable waste fuels used in cement plants
	median	80th percentile	median	80th percentile		
	Limit values in mg/kg dry matter (AT values converted from mg/kg assuming a calorific average value of 18 GJ/t. FR converted from ppm and %)					
Arsenic	36	54	90	135	13	NA
Antimony	126	180	630	900	120	NA
Lead	360	648	1350	2430	200 – 400	6'000
Cadmium	4.14 [1]	8.28 [1]	15.3	30.6	9	NA
Chromium, total	450	666	1710	2520	120 – 250	1'000
Cobalt	27	48.6	81	144	12	1'000
Copper	NA	NA	NA	NA	300 – 700▲▲	2'000
Nickel	180	324	630	1'080	100	'1000
Mercury	1.4	2.7	6.8	13.5	1.2	10
Thallium	NA	NA	NA	NA	2	NA
Zinc	NA	NA	NA	NA	NA	150'000
Tin	NA	NA	NA	NA	70	NA
Manganese	NA	NA	NA	NA	100 – 500	1'000
Vanadium	NA	NA	NA	NA	25	NA
PCB/PCB+PCT*	NA	NA	NA	NA	NA	50
PCP (Pentachloro-phenol)	NA	NA	NA	NA	NA	50

13 German Ordinance: Verordnung des Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft und des Bundesministers für Wirtschaft, Familie und Jugend über die Verbrennung von Abfällen (*Abfallverbrennungsverordnung* – AVV)
https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20002239

14 German Ordinance: Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen, September 2005, Leitfaden zur energetischen Verwertung von Abfällen in Zement-, Kalk- und Kraftwerken in Nordrhein-Westfalen
https://www.th-owl.de/fb8/fileadmin/download_autoren/immissionsschutz/Interpretation/NRW0509yyLeitfEnergVerw02.pdf

15 European Commission, Reference Document on Best Available Techniques in The Cement, Lime and Magnesium Oxide Manufacturing Industries, May 2010, Table 4.18
http://eippcb.jrc.ec.europa.eu/reference/

Total chlorine	NA	NA	NA	NA	NA	4
∑ As+Ni+Co+Se+Te+Cr+Pb+Sb+Sn+V	NA	NA	NA	NA	NA	10’000
Sulphur	NA	NA	NA	NA	NA	120’000
Other halogens (bromide+iodide+ fluoride)	NA	NA	NA	NA	NA	5’000
Alkalis (Na_2O+K_2O)	NA	NA	NA	NA	NA	150’000
Phosphates (P_2O_5)	NA	NA	NA	NA	NA	150’000

*PCB: polychlorinated biphenyl; PCT: polychlorinated terphenyl

[1] For quality assured AFs (key number 91108 according to German Ordinance on the list of waste, BGBl. II Nr. 570/2003, in the current version) a limit of 8.1 mg/kg (median) and 12.6 mg/kg (80th percentile) applies. (Assuming a calorific average value of 18 GJ/t)

▲referred to a calorific value of dry matter of at least 20 GJ/t (± 2,000 MJ/t), respectively for the high caloric fraction from municipal waste the calorific value amounts to 16 GJ/t.

▲▲Violation of limit due to inhomogeneity valid in individual cases

Annex 7 – Justification for the exclusion of certain waste material from co-processing

1. Radioactive waste

Radioactive waste is normally excluded from "classical" waste management, and therefore specific regulations have to be applied according to international agreements. This means that radioactive waste cannot be treated under the regulations of municipal and industrial waste and special permissions for its treatment are required. The procedure is normally stipulated in national nuclear laws. Cement plants are not suited to handle radioactive waste.

However, there is a borderline case for those wastes that have a low dose of radioactivity (e.g. waste from research, cleaning devices or in medical entities). Following the recommendations from the International Atomic Energy Agency and other organizations, many countries define certain waste as low radioactive if the radiation of the material to humans does not exceed 10 µSv per year. For this case a restricted or even an unrestricted clearance for handling this waste within an integrated waste management scheme could be given. At the international level, there is still a big discrepancy on procedures for clearance, and no uniform levels are given. As it is very difficult for most companies and/or authorities to provide evidence that the threshold limit value of 10 µSv could be assured at any time, it is recommended not to use any kind of radioactive waste for pre- and co-processing.

2. Asbestos-containing waste

Asbestos is the name given to a group of minerals that occur naturally as masses of long silky fibers. Asbestos is known for its unique properties of being resistant to abrasion, inert to acid and alkaline solutions, and stable at high temperatures. Because of these attributes, asbestos was widely used in construction and industry. Asbestos fibers are woven together or incorporated within other materials to create many products.

Airborne asbestos fibres are small, odourless and tasteless. They range in size from 0.1 to 10 microns in length (a human hair is about 50 microns in diameter). Because asbestos fibres are small and light, they can be suspended in the air for long periods. People who get in contact with asbestos may inhale fibers. Once inhaled, the small, inert asbestos fibers can easily penetrate the body's defenses. They are deposited and retained in the airways and tissues of the lungs and can cause cancer. Due to negative health impacts, the use of asbestos has been forbidden in most countries for around 25 years.

Asbestos-containing materials can be classified into one of three types: sprayed or trowelled-on material (e.g. ceilings or walls), thermal system insulation (e.g. plaster cement wrap around boilers, on water and steam pipe elbows, tees, fittings, and pipe runs), or miscellaneous materials (e.g. floor tile, sheet rock, ceiling tiles, automotive friction products). Millions of tons of asbestos products will be transferred into waste material in the future, especially in developing countries and not all countries have national regulation on the handling and final disposal of this significant waste stream.

Asbestos-containing waste could be treated in specially equipped rotary kilns at a temperature > 800°C for a certain time. The asbestos minerals would be transformed into other minerals like olivine or forsterite. Therefore co-processing could be, from a technical point of view, an option for treatment of asbestos waste. However, sanitary landfilling must be regarded as the most appropriate way of final disposal as the material can be disposed undisturbed and does not provoke the release of unwanted fibers into the air. Once safely dumped, the asbestos waste does not have further negative environmental impacts. As the availability and new installation of sanitary landfill become more and more a problem, requests for co-processing asbestos might arise in the future. However before cancelling asbestos from the banned list, detailed investigations are required in particular on occupational health and safety in the whole supply chain. Further, asbestos-specific regulations have to be introduced and enforced by the national authorities.

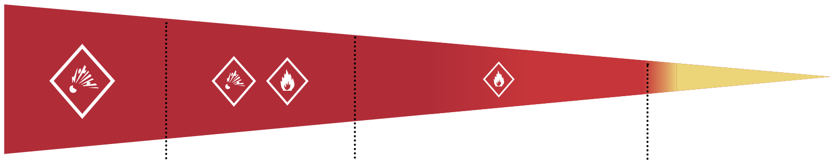
3. Explosives and Ammunition

Explosives are any chemical compound, mixture or device capable of producing an explosive-pyrotechnic effect, with substantial instantaneous release of heat and gas. Examples are nitro-glycerine, fireworks, blasting caps, fuses, flares, ammunition, etc. Reasons to exclude them from co-processing are safety due to the risk of uncontrolled explosions during pre-processing activities, transportation or handling, explosive reactions in the cement kiln would have and negative impact on process stability.

4. Self-reactive thermally unstable compounds
These compounds are typically excluded from pre-processing as the materials hold specific hazards that under normal operating conditions are likely to undergo a strongly exothermic decomposition even without participation of oxygen (air). Some of the material will detonate or deflagrate rapidly or is capable of undergoing a thermal explosion – it should thus be seen in the same light as an explosive material.

A material in this category is for example benzoyl peroxide. As a pure chemical it is deemed to be a strong oxidizer which can react violently with combustibles (GHS classification type A / B). However when mixed into cream (typically 5 – 20%) for use as an acne treatment it is deemed to be not flammable by OSHA criteria.

Table 20: Classification of self-reactive substances.[16]

Hazard classes	Self-reactive substances and mixtures/ Organic peroxides (two separate hazard classes having the same categories and are therefore grouped)				
GHS labelling					
GHS classification	**type A**	**type B**	**type C+D**	**type E+F**	**type G**
Signal word		**Danger**		**Warning**	
H statements	**H240:** heating may cause an explosion.	**H241:** heating may cause a fire or explosion.	**H241:** heating may cause a fire.		

5. Anatomical, infectious, and health care waste
Infectious and health care wastes are generated in the human medical, veterinary care and in research. Examples are used blood transfusion bags, blood contaminated bandages, dialyse filters, injection needles, and also parts of the body and organs. The disposal requires special hygienic and work safety requirements on handling, packaging and transportation.

The conditions in the cement kiln would be appropriate to treat infectious and health care wastes, but would require special precautions on health and safety in the supply chain of this waste. As the required H&S conditions cannot be fully assured, co-processing is presently not recommended. However, the problem of inadequate handling of health care waste has persisted for years, especially in developing countries. Although it is well known that segregating waste at the source is the most important step in managing health care waste, this principle is not always applied. Even less attention is given to the ultimate safe storage and final treatment (sterilization or microwave) of infectious waste.

16 EPFL, 2014, Generally Harmonised System of classification and labelling of chemicals

6. Waste electrical and electronic equipment

Waste electrical and electronic equipment (WEEE) is composed of computers and accessories, entertainment electronics, communication electronics, toys but also white goods such as kitchen devices or medical apparatus. WEEE contains on one hand substances harmful to health and the environment such as Cl, Br, P, Cd, Ni, Hg, PCB and brominated flame retardants in high concentration, often higher than threshold limit values in the permits. On the other hand, the scrap contains so much scarce precious metals that all efforts have to be undertaken to recycle it. Co-processing of the plastic parts of the electronic waste would be an interesting option but requires disassembling and segregation first.

7. Entire Batteries

Batteries can be classified as automotive batteries, industrial batteries and portable (consumer) batteries. Automotive batteries are mainly lead-acid batteries; industrial batteries comprise both lead-acid batteries and Ni-Cd batteries. The portable battery consists of general purpose batteries (mainly Zn carbon and alkaline manganese batteries), button cells (mainly Hg, Zn air, Ag_2O, MnO and Li batteries) and rechargeable batteries (mainly Ni-Cd, Ni-metal hydride, Li-ion and sealed lead-acid batteries). Most of these substances are harmful to health and the environment. Co-processing of batteries would lead to an undesirable concentration of pollutants in the cement and the air emissions. Also, some battery contents, such as Hg, Ni or Cd, exceed limit values for AFR. In addition, commercially viable battery recycling plants have been successfully introduced.

Annex 8 – Permit model

Sender: Licensing authority

Addressee: Company

I.

By these presents, pursuant to articles ....Act.... you shall be granted the permit to build and operate a plant for the production of cement with co-processing waste fuel with an output of ...t/d cement in... (place)....(street, correct address)

II. Plant Components

- rotary kiln with flue gas channels, stack
- raw material storage
- fuel storage (primary fuel, secondary fuel)
- crushers, mills, coolers
- conveying facilities
- electrostatic filter
- waste processing, supply station
- .....

III. Application Documents

1. Topographical map
2. Constructions documents:
    - key plan
    - drawings
    - building specification
3. Diagrammatic section of the plant
4. Machine site plan
5. Description of the plant and operation of the plant, the terms of normal working conditions
6. Description of the emission situation
    - the technology for prevention the pollution
    - contents of quantities of emissions
7. Description of secondary fuels: generation, processing, utilizing installation, supply, quality assurance system
8. Environmental assessments
    - Air pollution emission prognosis (e.g. dust, NOX, SO_2, heavy metals, PCDDs/PCDFs)
    - Noise emission prognosis
    - Odor emissions
9. Maintenance of industrial and occupational health and safety standards
10. Description of energy saving techniques and/or measures
11. Description for public information

IV. Plant Data

Output: ....t/d cement
Primary fuel: coal dust, heating oil,
Secondary fuel: solid fuels, liquid fuels, ...

V. Collateral Regulations

1 Air pollution control

1.1 All waste gases must be collected and must be discharged in a controlled manner via stack.

1.2 Emission measurements must satisfy the following requirements. They must be

- representative and comparable with one another
- permit uniform evaluation
- permit monitoring and verification of compliance with emission limit by state-of-the-art measurement practice

1.3 According to the EU directive 2010/75 on industrial emissions, the emission in the exhaust air of waste gas purification plants shall not exceed the following mass concentrations, always referred to standardized conditions (273 K; 1013 hPa) after deduction of moisture. Reference oxygen content 10%

Pollutant (daily average value in mg/m³)	**Total emission limit***
Particulate emissions (Total dust)	30
HCL	10
HF	1
NOx	500
SO_2	50**
TOC	10**
Dust constituents and filter-slipping metals, metalloid and compounds there of:	
Cd + Tl	0,05
Hg	0,05
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V	0,5
PCDDs and PCDFs	0,1 ng I-TE/m³

* Emission limits are fixed on basis "EU directive 2010/75 on industrial emissions" but local authorities may establish special limits in case by case

** Exemption my be authorized by competent authority in cases where TOC and SO_2 do not result from the co-incineration of waste

1.4 Monitoring of emissions:

- Substances contained in dust, HCL, PCDDs/PCDFs
  For the monitoring of emissions, single measurements are to be conducted.
  The emission limit values are being observed if single measurement results do not exceed the fixed emission limit value. Measurements have to be repeated at least once per year and be performed by independent experts.
- Dust, NOX, SO_2
  In order to monitor emissions, continuously measuring devices with automatic evaluation are to be installed.
  The result of the continuous measurements must be recorded.
  The measuring instruments have to be tested with regards to their functioning once a year by independent experts
- CO (limit value can be set by competent authority)

1.5 Qualified laboratories
To ensure a uniform measurement practice, representative measurement results and comparable quality procedures, qualified laboratories are to be commissioned with sampling and analysis activities and calibration procedures.
The location and configuration of the sampling point is to be coordinated with the competent authorities (and the commissioned laboratory, where applicable).

2 Waste fuel control

2.1 Monitoring of quality assurance for co-processing waste fuels

- point of generation (producer)
  - listing the waste according to type
  - contractual agreement over permissible quality and composition of the waste
  - documentation of quantities disposed of

- **processing installation (incoming)**
  - routine sampling and analysis, retention samples
  - documentation of the quantities received and processed
  - routine sampling and analysis by independent expert
- **processing installation (outgoing)**
  - routine sampling and analysis, retention samples
  - documentation of the outgoing quantities
- **utilizing installation (cement kiln, incoming)**
  - routine sampling and analysis, retention samples
  - documentation of the incoming quantities
- **parameters investigated**
  - calorific value, moisture chlorine, sulfur, ash and ash components
  - heavy metals (Cd, Tl, Hg, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V)
  - PCBs, PAH, etc.
  - maximum value, median value of the level of pollutants in the waste mix.

Pollutant limits in waste fuels for co-processing [17]

	median value (ppm)	**maximum value (ppm)**
Cadmium		
Thallium		
Mercury		
Antimony		
Arsenic		
Cobalt		
Nickel		
Selenium		
Tellurium		
Lead		
Chromium		
Copper		
Vanadium		
Manganese		
Tin		
Beryllium		
Chlorine		
PAH		
Sulfur		
PCBs		

17 Must be defined by the local authorities

2.3 Waste fuel catalogue for co-processing in cement kiln

Waste key / group	description of the co-processing fuel

3 Monitoring safe combustion

- The combustion process has to be monitored continuously using modern process control technology,
- The main parameters for analysis of the waste materials (calorific value, chemical composition, etc.) must be put into the process control system on a continuous basis,
- Regulations of primary energy have to follow in reliance on secondary fuel data,
- Waste fuels may only be supplied during normal continuous operation within the rated output range.

3.1 Safety regulations

For supervising the parameters listed below, they should be linked to one another by a computer-controlled logic system e.g.:

- Gas temperature less than 900°C at kiln inlet
- Temperature of material at kiln outlet less than 1250°C
- CO level above a value to be established by trial (Vol.%)
- Inadmissible control deviations in the set point/actual value comparison for the primary and secondary fuel feed
- Raw meal feed of less than 75% of the max. possible quantity
- Negative pressure before the exhaust gas fan below the value required at rated output
- Permissible O_2 level lower than inspection measurements require
- Permissible NOx level above 500 mg/m^3
- Failure of burner
- Dust level above permissible limit.

(This should ensure rapid detection of any disruption to normal operation and use appropriate response systems to prevent uncontrolled combustion of residues)

VI. Noise

As far as noise must be taken into consideration, the noise emission limit values shall be determined in dependence of existing surrounding development.

VII.

Sewage water (if applicable)

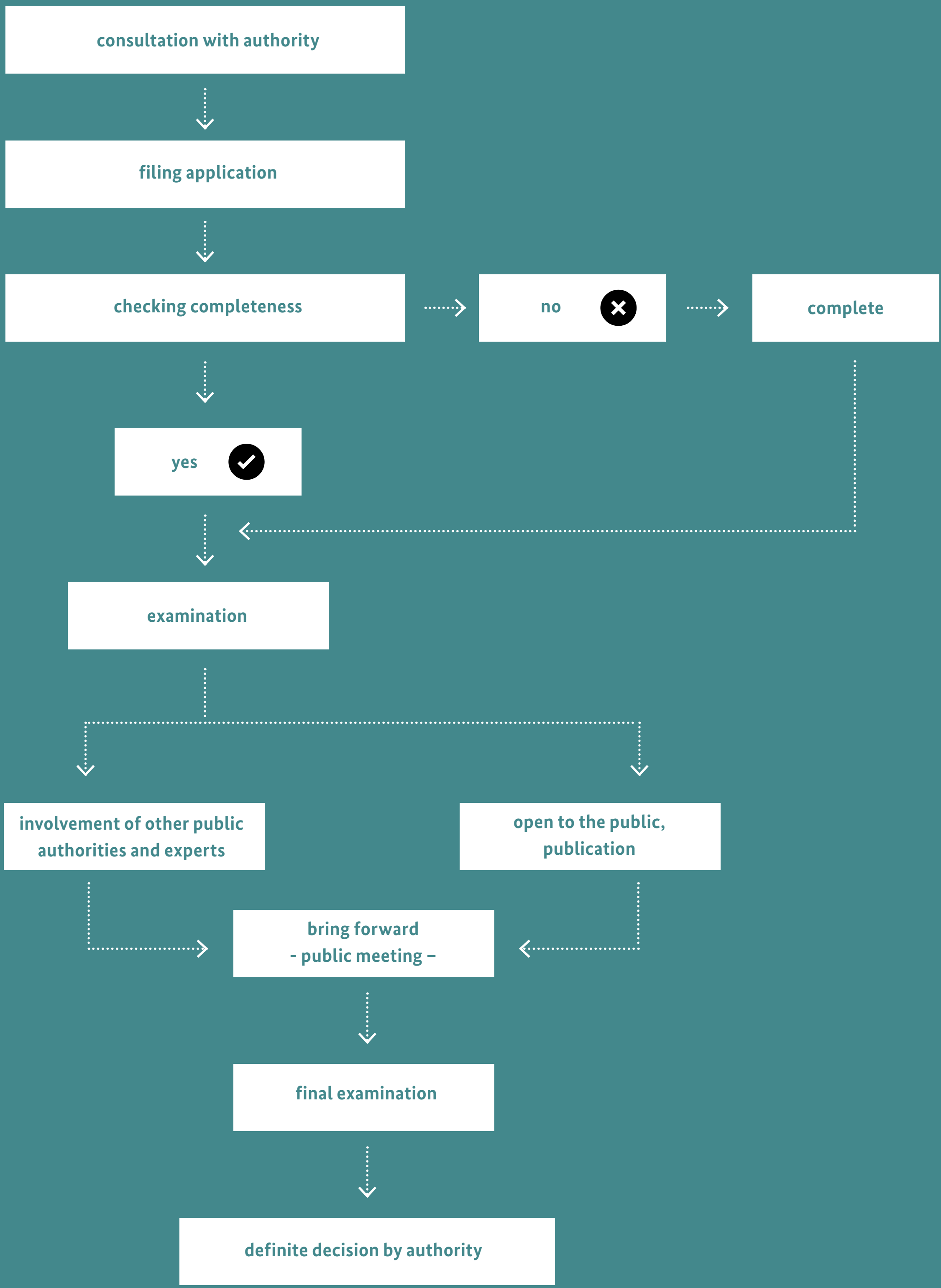
VIII. Reasons

(Reasons for a permission for co-processing waste)

- environmental assessment
- air pollution control
- waste management, waste hierarchy
- public involved.

Annex 9 – Permitting process

Figure 23: Flow chart of a permitting process.



Annex 10 – Information on test burns

Test burns are required in some regulations and conventions for the verification of the *destruction and removal efficiency* (DRE) or the *destruction efficiency* (DE) of certain principal organic hazardous compounds (POHC) in a cement kiln.

The DRE is calculated on the basis of mass of the POHC content fed to the kiln, minus the mass of the remaining POHC content in the stack emissions, divided by the mass of the POHC content within the feed. The DRE considers emissions to air only. The DE considers all out-streams (liquid and solids) in addition to the air emissions and is the most comprehensive way of verifying the performance.

Test burns with non-hazardous AFR are not a regulatory requirement but are sometimes done to evaluate the behavior of the process and the influence on main gaseous emissions and the cement clinker quality when feeding AFR to the kiln. Such simplified tests are usually conducted by process engineers at the cement plant using already installed online monitoring equipment and operational process data. However, test burns with hazardous compounds require professional supervision and independent verification.

Cement kilns co-processing hazardous wastes in the EU are not required to carry out a test burn but must comply with emission limit values of the Industrial Emission Directive. In the US, cement kilns co-processing hazardous wastes must perform a test burn to demonstrate the combustion performance on selected hazardous wastes to demonstrate the DRE for POHCs in the waste stream. The test burn must fulfil three major requirements regarding combustion performance, whereas the DRE is the most important: POHCs must be destroyed and/or removed to an efficiency of 99.99% or better; POPs wastes must achieve a DRE of 99.9999%. The remaining two requirements deal with emissions of particulates and gaseous hydrogen chloride.

A destruction and removal efficiency of 100% will not be possible to establish due to limitations in the analytical instruments. The Stockholm and Basel Conventions require a DE test for kilns aiming to treat POPs or POPs waste. Taking into consideration the inherent features of a cement kiln – the high temperatures, long residence times, excess oxygen etc. – a test burn seems to be redundant. However, a test burn is actually the only way to prove the destruction performance of a kiln and its ability to destroy hazardous wastes in an irreversible and sound way. However, the design and the conditions of the test are crucial. Earlier data that indicated cement kiln DRE results below 99.99% are either from outdated sources or improperly designed tests, or both.

In the early years of development of this technology and the sampling and analytical techniques to evaluate its environmental performance, there were several instances where POHCs were selected that did not meet the necessary criteria. For example, a major problem with many early tests was that the POHCs selected for DRE evaluation were organic compounds that are typically also found at trace levels in the stack emissions from cement kilns that burn traditional fossil fuel. While these *products of incomplete combustion* (PICs) were emitted at very low levels, they nonetheless greatly interfered with the measurement of POHC destruction, i.e. DRE could not be properly measured if POHCs used in testing were chemically the same or closely related to the type of PICs routinely emitted from raw materials. In some instances, operational factors during the testing or sampling and analytical techniques contributed to low DRE results.

The US test burn permitting process, originally designed to determine how effectively an incinerator is able to operate under specifiable "worst cases", is however regarded as unnecessarily complex and costly, and has discouraged cement plant owners from adopting the test burn concept. An alternative approach will in most cases provide the same qualitative information: a „one-run“ test burn investigating the destruction performance when feeding a suitable hazardous waste combined with a baseline study measuring the „blank“ emissions when no hazardous waste is introduced, both tests done under normal process operating conditions. A cement plant is operated continuously, i.e. usually more than 330 days a year, and such a test scheme will together with a feasibility study and an environmental impact assessment provide sufficient information on the performance for the cement kiln in question. The following conditions should be fulfilled in the one-run test burn:

- The destruction and removal efficiency for the hazardous compound should be at least 99.99%. Chlorinated aromatic compounds should be chosen as a test compound if available because they are generally difficult to destroy. For POPs, a DRE of 99.9999% should be achieved.
- The cement kiln should meet an emissions limit for PCDDs/PCDFs of 0.1 ng TEQ/Nm_3 both under baseline and test burn conditions.
- The cement kiln should comply with existing national emission limit values.

Such an approach for performance verification will, together with adequate safety arrangements, input control and operational procedures, secure the same level of environmental protection as the current EU and US regulation.

Annex 11 – Structure of a waste management plan

Table 21: Elements of a waste management plan in European Union.[19]

	Background
1	Overall waste situation or problem in a territory
2	Regional framework legislation (e.g. EU)
3	National legislation
4	Description of national waste policy and prevailing principles to address Point 1 above, in line with the waste hierarchy
5	Description of objectives set in specific areas
6	Inputs from the consultation process
	Description of objectives set in specific areas
1	Waste amounts, e.g.: a) waste streams b) waste sources c) waste management options
2	Waste collection and treatment options for the above
3	Waste shipment
4	Organization and financing
5	Assessment of previous objectives
	Planning
1	Assumptions for planning
2	Forecast in terms of waste generation, total and per waste stream
3	Determination of objectives for forecasted: a) waste streams b) waste sources c) waste management options
4	Plan of action, including measures for achieving objectives: a) collection systems b) waste management facilities c) responsibilities d) economy and financing

19 European Commission Directorate-General Environment, 2012, Preparing a Waste Management Plan, A methodological guidance note *http://ec.europa.eu/environment/waste/plans/pdf/2012_guidance_note.pdf*

Annex 12 – Key questions for baseline assessment focusing on inclusivity

- What is working and what is not working in the host community of the cement producer, in terms of the management of waste?
- To which of the key problems does pre- and co-processing potentially provide a solution? Do the owners of those problems feel that pre- and co-processing is indeed a useful strategy to solve them?
- What quantities and types of materials are not being captured by the solid waste system or the value chains at the time of the baseline, and where are they going? What are the drawbacks and benefits of this lack of coverage of the solid waste system?
- Which entities have placed these products (e.g. packaging materials) on the market?
- Why are these materials escaping from the solid waste system?
- How much of this stream of materials is ending up in the marine environment in the short, middle, and long term? Do they stay in their country of origin or do they migrate into other jurisdictions?
- To what extent are the materials which would be suitable for pre-processing into AFR for co-processing in a cement kiln, already being valorized or claimed by public or private actors in the value chains?
- Who is responsible for cleaning these materials up and removing them from the marine environment, and who is bearing the costs, to the extent that they are removed?To what extent and under what conditions would the availability of co-processing options expand the capacity of the entire waste management system to prevent the movement of waste streams and fractions into the marine environment?
- Is there already sorting or processing infrastructure present in the jurisdiction, that could be deployed to pre-process waste and produce AFR?
- What are the risks and benefits to the cement producer of having access to processed AFR for co-processing in the cement kiln, and can these risks and benefits be quantified and monetized?
- What are the risks and benefits to the solid waste system and its host institutions to having access to co-processing of specific fractions in the cement kiln, and can these risks and benefits be quantified and monetized?
- What are the risks and benefits to the private recycling value chain companies, and their medium, small, semi-formal and informal suppliers, of co-processing of specific fractions in the cement kiln, and can these risks and benefits be quantified and monetized?
- Who should pay whom for co-processing or provision of AFR, and how does this change due to economic circumstances, the marketability of certain fractions to the value chains, the obligations of producers to manage the end of life of their products and packages, or the future development of formal disposal facilities such as sanitary landfills or WtE mass burn incinerators?

Annex 13 – Template for master data file for common used waste

AFR / WASTE PROFILE

1 of 4

Designation		Industry of origin	
Waste codification (national)		Codification according to Holcim	
Potential (and/or)	☐ AR ☑ AF	Date	

Source				User			
waste generator	○	platform	○	plant	○	platform	○
Company				Company			
Adress				Adress			
Contact				Contact			
Phone				Phone			
Fax				Fax			
E-mail				E-mail			

AFR / Waste generating process	

Principal constituents	Chemical formula	Minimum	Average	Maximum
		%	%	%
		%	%	%
		%	%	%
		%	%	%
		%	%	%

AFR / Waste availability

from process	○	t / year		Expected duration				
storage capacity				spot	○	> 1 year	○	< 1 year ○
from stock	○	stock	t	cost / t				

AFR / Waste delivery

Timing of delivery		Transport					
Continous over the year	○	Rail	○	Drums	○	Tank truck	○
Irregular / seasonal	○	Big bag	○	IBC	○	Bulk truck	○

Macroscopic properties

solid	○	Max. particle size / mm				Dust generation	high	○ ○ ○	low
		>100	○	10 - 1	○	Foreign bodies	frequent	○ ○ ○	none
		100 - 10	○	< 1	○	Flowability	high	○ ○ ○	low
		homogeneous		☐ yes	☐ no	Stickiness	high	○ ○ ○	low
sludge	○	homogeneous		☐ yes	☐ no	Stickiness	high	○ ○ ○	low
						Foreign bodies	frequent	○ ○ ○	none
liquid	○	aqueous	○	organic	○	Viscosity	high	○ ○ ○	low
		Different phases			○	Particles	much	○ ○ ○	none
						Sedimentation	strong	○ ○ ○	weak
Other characteristics									
Color	dark	○ ○ ○	light			Odor	strong	○ ○ ○	no

Banned wastes - not allowed as per AFR-policy

Not to be Processed			**Not to be Co-Processed**		
Radioactive waste	☐ yes	☐ no	Electronic fraction of electrical and electronic waste (e-waste)	☐ yes	☐ no
Asbestos-containing waste	☐ yes	☐ no	Whole batteries as a targeted material stream	☐ yes	☐ no
Explosives & ammunition / weapons	☐ yes	☐ no	Waste of unknown or unpredictable composition, including unsorted municipal waste	☐ yes	☐ no
Anatomical medical waste	☐ yes	☐ no		☐ yes	☐ no
	☐ yes	☐ no		☐ yes	☐ no

AFR / WASTE PROFILE

2 of 4

CHEMICAL & PHYSICAL PROPERTIES

Designation	0		Industry of origin	0	
Analytical laboratory			**Information source**		
Company			Date	00.01.00	
Adress			Sample information		
			one spot sample	◯	Composite sample ◯
Contact			taken by		
Phone		Fax	Comments		
Email					

Physical and chemical properties

	Min.	Average	Max.		Min.	Average	Max.
H_2O content as delivered %				Boiling point °C			
Viscosity Pa				Melting point °C			
Density kg / m^3				Residue on ....mm %			
Bulk density kg / m^3				Residue on ....mm %			
pH				Residue on ....mm %			
Water soluble compounds							

Organic properties

Sample preparation	air dried ◯	dried ◯	other				
	Sample Average	estimated Min.	Max.		Sample Average	estimated Min.	Max.
Ash content %				S %			
Volatiles content %				C %			
CV gross MJ / kg				H %			
CV net MJ / kg				PCB ppm			
Flash point °C				PCT ppm			
TOC %				Phenols ppm			

Inorganic properties

Sample preparation		air dried ◯	dried ◯	other				
Mineral components		Min.	Average	Max.		Min.	Average	Max.
Quartz %					Other			
Main oxides	L. o. i. %				Trace elements: Cd ppm			
Main oxides	SiO_2 %				Hg ppm			
Main oxides	Al_2O_3 %				Tl ppm			
Main oxides	Fe_2O_3 %				As ppm			
Main oxides	CaO %				Ni ppm			
Main oxides	MgO %				Co ppm			
Main oxides	SO_3 %				Se ppm			
Main oxides	K_2O %				Te ppm			
Main oxides	Na_2O %				Cu ppm			
Main oxides	TiO_2 %				Pb ppm			
Main oxides	Mn_2O_3 %				Sb ppm			
Main oxides	P_2O_5 %				Sn ppm			
Halogenes, others	F %				V ppm			
Halogenes, others	Cl %				Be ppm			
Halogenes, others	Br %				Ba ppm			
Halogenes, others	I %				Mn ppm			
Halogenes, others	CN %				Zn ppm			
Halogenes, others	NH_3 %				Cr ppm			

AFR / WASTE PROFILE

HEALTH & SAFETY

3 of 4

Designation	0	Industry of origin	0

Material safety data sheet

available	○	not available	○	

Hazards identification

Inflammable	☐	Irritant	☐	By eye contact	☐
Corrosive	☐	Harmful	☐	By skin contact	☐
Reactive	☐	Toxic	☐	By inhalation	☐
Respirable	☐	Carcinogen	☐	By ingestion	☐

Risk of hazardous reactions

with ↓ \ to →	Toxic vapour	Ignition	Explosion	Polymerisation	Solidification
High temperature	☐	☐	☐	☐	☐
High pressure	☐	☐	☐	☐	☐
Water	☐	☐	☐	☐	☐
Air	☐	☐	☐	☐	☐
Acids	☐	☐	☐	☐	☐
Bases	☐	☐	☐	☐	☐
Oxidants	☐	☐	☐	☐	☐
Reductants	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐
Comments					

Personal protection

Acid resistant clothes	☐	Safety helmet	☐	Safty gloves	☐
Full protection mask	☐	Safty glasses	☐	Semi-protection mask	☐

First aid

Appropriate measures	
Inappropriate measures	

Fire instruction

Appropriate measures	
Inappropriate measures	
Specific risks / instructions	

Spill instructions

Clean-up procedures	
Recovery procedures	
Disposal procedures	
Contact in urgent cases	

Transport

Hasard code		Transport code		Waste code	
Comments					

AFR / WASTE PROFILE

4 of 4

PLANT HANDLING & APPLICATION

Designation	0			Industry of origin	0		
Classification (see ATR)				HARP-Code (see ATR)			
Actual amount consumed		t / year		t / h (average)		t / h (max.)	

Pretreatment

drying	☐	grinding	☐	screening	☐	shredding	☐
mixing	☐	other:					
Comments							

Storage

open storage	☐	covered storage	☐	sealed floor	☐	non-sealed floor	☐
Bunker	☐	Silo	☐	Tank	☐	Pit	☐
drums	☐	big bag	☐	IBC	☐	Moving floor cont.	☐
other:				Storage capacity:			
Comments							

Extraction from storage

Front end loader	☐	Live bottom feeder	☐	Aeration ☐	Mechanical outlet activation		☐
Crane	☐	Reclaimer	☐	other:			
Comments							

Transport from storage to process

Front end loader	☐	Crane	☐	Chain conveyor	☐	Bucket elevator	☐
Hydraulic	☐	Pump type:		Screw conveyor	☐	Belt conveyor	☐
Pneumatic	☐			other:			
Comments							

Dosing

gravimetric	☐			volumetric	☐		
Belt scale	☐	Impact flowmeter	☐	Rotary valve	☐	Belt feeder	☐
Lossweight feeder	☐	Coriolis flowmeter	☐	Positive Displacement Pump	☐	Screw feeder	☐
Rotor weigh feeder	☐	other:				other:	
Comments							

Feed to process

Raw mat. crusher	☐	Raw mill	☐	Preheater	☐	Kiln inlet	☐
Preblending bed	☐	Slurry mill	☐	Lepol grate	☐	Mid kiln	☐
Slurry basin	☐	Coal mill	☐	Calciner	☐	Next to main flame	☐
other:						Main burner	☐
Comments							

Quality control

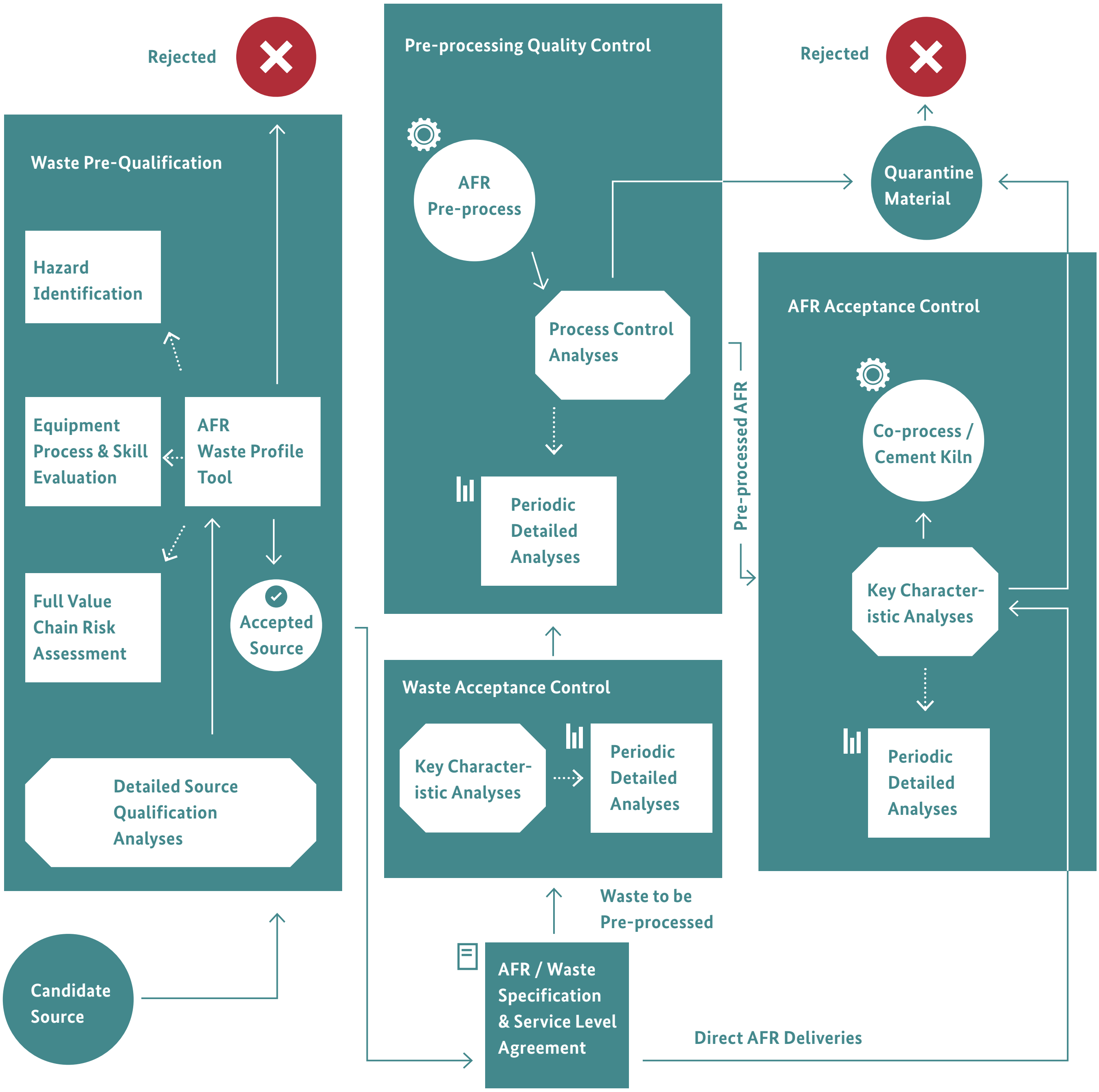
Comments	

Limiting factors for utilisation

Market availability	☐	Handling problems	☐	Feeding capacity	☐	Cost	☐
Main oxides	☐	Chlorids	☐	Trace elements	☐	Toxicity	☐
Water content	☐	Permits	☐	other:			

Annex 14 – AFR quality control scheme

Figure 24:
AFR quality control scheme.



Annex 15 – Situation analysis – how to do it

The following research tools are examples of how to do a situation analysis. The best will be to choose research tools that suit both your and your stakeholders' needs:

- **Door knocking** – probably the least formal and most effective way to engender community spirit about your company in the neighborhood.
- **Interviews** – one-on-one interviews provide you with concentrated information about a particular topic and the opportunity to probe further on specific points as needed.
- **Questionnaires** – these include in person, telephone or mail surveys. Random selection of respondents is key to obtaining objective survey results.
- **Needs assessment** – conducting a needs assessment with a small ‚focus' group of stakeholders is a formal method to gain valuable information about stakeholder needs and expectations. Focus groups can either be internal or external. The following four steps are recommended in conducting a needs assessment.
- **Media monitoring** – this technique is used to gauge the company reputation. This includes analyzing positive, negative or neutral stories in the media, number of mentions, length of stories, content and focus, etc. You can then interview selected journalists to gain more in-depth information.

Step I: Identify users and uses of the needs assessment

- Identify the persons who will act on the assessment.
- Identify the use of the assessment e.g. provide a basis for the strategic plan.

↓

Step II: Describe the context

- What is the physical and social environment of your activities?
- When have you started, or are you just starting?
- Is this an initial assessment or are you trying to verify the appropriateness of your activities?

↓

Step III: Identify needs

- Describe circumstances / problems of the stakeholders.
- Suggest possible solutions to their needs and analyse likely effectiveness, feasibility and sustainability.

↓

Step IV: Meet needs and communicate results

- Recommend actions based on the needs, problems, and solutions identified.
- Communicate the results of the assessment to your stakeholders.

Annex 16 – Approaches to informal sector integration

Designing actions to integrate the informal recycling sector should follow a holistic approach based on mutual benefit and trust, and addresses mainly municipal decision makers and operators of pre-processing.

- Global partnerships, national and local actions should take into account existing experiences and develop locally adapted approaches. Standards for waste handling systems at national, local and ward levels should have provisions for informal sector inclusion.
- Design waste management plans and feasibility studies that allow informal sector integration.
- Enable meetings and processes that make the informal sector's role and contributions for waste management visible.
- Investigate and track the performance and impact of the existing informal valorization and service sectors.
- If it ain't broke, don't fix it: better to build on what is working, than abandon or destroy it in favor of something unknown that might or might not work.
- DO fix what doesn't work: Not every aspect of the informal sector is positive, and problems need to be recognized, and confronted.
- Allow access to waste: it is a fundamental issue and entails legal rights to collect and recycle and the physical role of the informal recycling sector (IRS), such as providing primary collection services or secondary sorting at material recovery centers.
- Consider light regulation and integration: Create a portfolio of low-threshold formalization measures, which combines regulation with facilitation of improvements.
- Support the self-organization of the IRS: the transition from autonomous to group labor is always a significant challenge, and may come with resistance towards collective organization, but having reliable contact partners in some form of organizational structure is essential for engaging with formalized business partnerships.
- Providing capacity building support for IRS organizations such as: training in sorting, processing, recycling techniques and value added services; development of feasible and sustainable business strategies; improvement of managerial skills (business management, accounting, marketing, negotiation skills); maintenance of work ethics and organization/team work.
- Build structures that link the formal and the informal along the value chain: It is essential for local authorities to create structural relationships between the solid waste system and the formal and informal valorization sector.
- Promoting the participation of waste generating businesses and industries: Encourage companies to invest in the social enterprises of waste pickers and informal waste workers by providing financial as well as non-financial support.
- Affordable technologies are the most practical and sustainable – It is therefore essential to moderate technical ambitions for new disposal and processing technology, to keep them affordable in the short- a nd middle- term.
- Provide occupational health and safety measures such as protective clothing and availability of health care services. Special measures at pre-processing stations might be considered – provision of basic health insurance, trainings and digital payments may be useful incentives to interest informal workers in long-term cooperation.

Abbreviations

General abbreviation

AF	Alternative Fuels
AFR	Alternative Fuels and Raw Materials
AR	Alternative Raw Materials
ASR	Automotive Shredder Residues
BAT	Best Available Technology
BPD	Bypass Dust
BREFs	Best Available Techniques Reference Document
CAPEX	Capital Expenditures
CeMAP	Cement Manufacturers Association
CIS	Commonwealth of Independent States: (Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan (associate member), Ukraine, and Uzbekistan)
CKD	Cement Kiln Dust
COD	Chemical Oxygen Demand
CSI	Cement Sustainability Initiative
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DRE	Destruction and Removal Efficiency
EIA	Environmental Impact Assessments
EMS	Environmental Management System
ESIA	Environmental and Social Impact Assessment
E-PRTR	European Pollutant Release and Transfer Register
EU-ETS	EU Emission Trading Scheme
FAQ	Frequently Asked Questions
FHNW	Fachhochschule Nordwestschweiz (University of Applied Sciences and Arts Northwestern Switzerland
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWMO	Global Waste Management Outlook
GTZ	Gesellschaft für Technische Zusammenarbeit
H&S	Health & Safety
IEA	International Energy Agency
IED	Industrial Emissions Directive
IMPEL	Implementation and Enforcement of Environmental Law
IPCC	Intergovernmental Panel on Climate Change
IRRC	Integrated Resource Recovery Centre
IRS	Informal Recycling Sector
ITDI	Industrial Technology Development Institute
LCA	Life-Cycle Analysis
MBT	Mechanical Biological Treatment
MFA	Material Flow Analysis
MIC	Mineral Components
MSW	Municipal Solid Waste
NAMA	Nationally Appropriate Mitigation Action
NESHAP	National Emission Standard for Hazardous Air Pollutants
NGO	Non-Governmental Organization
OELs	Occupational Exposure Limits
OPEX	Operation and Maintenance Costs
POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
PRTR	Pollutants Release and Transfer Register

PTE	Potentially Toxic Elements
RDF	Refuse Derived Fuel
SDGs	Sustainable Development Goals
SRF	Solid Recovered Fuel
SWM	Solid Waste Management
TEQ	Toxicity Equivalent Quotient
TOC	Total Organic Compund
TRI	Toxics Release Inventory
WtE	Waste to Energy
WEEE	Waste Electrical and Electronic Equipment

Chemical abbreviation

Al	Aluminum
Al_2O_3	Aluminum oxide
Ag	Silver
Ag_2O	Silver-oxide
AHC	Aliphatic hydrocarbon
As	Arsenic
Br	Bromine
BTEX	Benzene, toluene, ethyl benzene, o-xylene, m-xylene, p-xylene
Ca	Calcium
CaO	Calcium oxide
$CaCO_3$	Calcium carbonate
Cd	Cadmium
CH_4	Methane
CHC	Volatile chlorinated hydrocarbons
Cl	Chlorine
Co	Cobalt
CO	Carbon monoxide
CO_2	Carbon dioxide
Cr	Chromium
Cu	Copper
Fe_2O_3	Iron oxide
H_2S	Hydrogen sulphide
HCB	Hexachlorobenzene
HCl	Hydrogen chloride
HF	Hydrogen fluoride
Hg	Mercury
K_2O	Potassium oxide
Na_2O	Sodium oxide
Mn	Manganese
MnO	Manganese oxide
NH_3	Ammonia
Ni	Nickel
NOx	Nitrogen oxide
O_2	Oxygen
P	Phosphorus
PAH	Polyaromatic hydrocarbons

Pb	Lead
SiO_2	Silicon oxide
Tl	Thallium
TCM	Tetrachloromethane
TCE	Trichlorethylene
Sb	Antimony
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PCDF	Polychlorinated dibenzofuran
PCDD	Polychlorinated dibenzodioxin
Pb	Lead
SO_3^{2-}	Sulfites
SiO_2	Silicon dioxide
SOx	Sulfur oxides
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TiO_2	Titanium oxide
TOC	Total organic carbon
SO_2	Sulfur dioxide
V	Vanadium
VOC	Volatile organic compound
Zn	Zinc

Units

Gt	Giga ton, 1,000,000,000 tons
KJ/GJ	Kilo joule, Giga joule
Mt	Mega ton, 1,000,000 tons
t	metric ton. Throughout this document ‘tons’ refer to metric tonnes (1000 kg).

Glossary

***Alternative fuels and raw materials* (AFR)**
Inputs to clinker production derived from waste streams that contribute energy and raw material.

ATEX
European directive on equipment and protective systems intended for use in potentially explosive atmospheres.

Capacity Development
Capacity development is the process of strengthening the abilities of individuals, organizations, companies, and societies to make effective and efficient use of resources. In the context of these Guidelines, capacity development comprises first of all the transfer of knowledge, experience, skills and values. It includes the improvement of management systems and the extension of networks. Change management and mediation in conflicting situations are essential parts of institutional development.

***Capital expenditures* (CAPEX)**
CAPEX buy contains required infrastructure, machinery, vehicles and installations to handle the waste streams.

***Operating expenditures* (OPEX)**
Operation and maintenance costs (OPEX) arise from running the infrastructure, machinery, vehicles and installations at a certain capacity. They include salaries, electricity bills, auxiliary materials, fuel, maintenance, environmental costs, costs for operational health and safety, lab analysis to monitor AFR composition and quality, insurance costs, taxes and others. For comparison reasons these costs are expressed on a yearly or per ton basis taking into account capacities, utilization rate and cost of capital, i.e. interest rates.

Clinker
An intermediate product in cement manufacturing produced by decarbonizing, sintering and fast-cooling ground limestone.

Concrete
A material produced by mixing cement, water and aggregates. The cement acts as a binder, and the average cement content in concrete is about 15%.

***Corporate social responsibility* (CSR)**
The commitment of business to contribute to sustainable development, working with employees, their families, the local community and society at large to improve their quality of life.

Dust
Total clean gas dust after dedusting equipment. (In the case of cement kiln main stacks, more than 95% of the clean gas dust has PM10 quality, i.e. is *particulate matter* (PM) smaller than 10 microns.)

Eco-efficiency
Reduction in the resource intensity of production, i.e. the input of materials, natural resources and energy compared with the output: essentially, doing more with less.

Electronic waste
This is waste from electrical and electronic equipment including all components, subassemblies and consumables which are part of the product at the time of discarding (def. according to EU-Directive 2002/96/EC from January 2003).

End-of-life application
Concrete debris which is not reused but disposed of in a landfill (“end of life”).

***Extended producer responsibility* (EPR)**
An environmental policy approach whereby producers take over the financial and/or organizational responsibility for collecting or taking back used goods, as well as sorting and treatment for their recycling.

Fossil fuels
Non-renewable carbon-based fuels traditionally used by the cement industry, including coal and oil.

Industrial ecology
Framework for improvement in the efficiency of industrial systems by imitating aspects of natural ecosystems, including the transformation of wastes to input materials; one industry's waste becomes another industry's input.

Kiln
Large industrial oven for producing clinker used in the manufacture of cement. In this report, "kiln" always refers to a rotary kiln.

Leaching
The extraction, by a leachant (de-mineralized water or others) of inorganic and/or organic components of a solid material, into a leachate by one or more physicalchemical transport mechanisms.

Lost time injury
A work-related injury after which the injured person cannot work for at least one full shift or full working day.

***Occupational health and safety* (OH&S)**
Policies and activities to promote and secure the health and safety of all employees, subcontractors, third parties and visitors.

Quality
Quality is defined as the degree to which a set of inherent characteristics fulfils requirements (def. according to ISO 9000).

SEVESO – Directive
European directive on technological disaster risk reduction.

Stakeholder
A group or an individual who can affect or is affected by an organization or its activities.

Stakeholder dialogue
The engagement of stakeholders in a formal and/or informal process of consultation to explore specific stakeholder needs and perceptions.

Waste
Any substance or object, which the holder discards or intends or is required to discard.

Notes

IMPRINT

Published by
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
Friedrich-Ebert-Allee 36 + 40
53113 Bonn
Germany
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The public part is being financed by:

Federal Ministry
for Economic Cooperation
and Development

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As at
January 2020

Design, graphics and layout
creative republic, Frankfurt/Germany

Printing
Druckerei Lokay e.K., Reinheim /Germany

GIZ and LafargeHolcim would like to express their sincere gratitude to all experts who contributed to the Guidelines, either as authors, as reviewers or by providing other valuable inputs. Our thanks also go to BMZ for financing the public part of the project.

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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