UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

TECHNICAL REPORT – ALTERNATIVE FUELS AND ALTERNATIVE RAW MATERIALS

Enhancing Productivity in the Indian Cement Sector

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2017

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LIST OF ABBREVIATIONS

AF	Alternative Fuel
ARM	Alternative Raw Materials
BAT	Best Available Technology
BREF	BAT Reference Document
Capex	Capital Expenditure
CPCB	Central Pollution Control Board
CSI	Cement Sustainability Initiative
C&D Wastes	Construction and Demolition Wastes
C&I Wastes	Commercial and Industrial Wastes
EIA	Environmental Impact Assessment
ERP	Enlarged Responsibility of the Producer
ISS	Industrial Sewage Sludge
JRC	Joint Research Centre (Europe)
MBT	Mechanical Biological Treatment
MSS	Municipal Sewage Sludge
MSW	Municipal Solid Wastes
Opex	Operation Expenditure
PCB	Polychloro Biphenyl
RDF	Refuse Derived Fuel
SOP	Standard Operation Procedure
SPL	Spent Pot Liner
SRF	Solid Refuse Fuel
TSR	Thermal Substitution Rate
UNEP	United Nations Environment Programme

ACKNOWLEDGEMENTS

The Technical Report – Alternative Fuels And Alternative Raw Materials was drafted in the context of project - Development and adoption of appropriate technologies for enhancing productivity in the cement sector - funded by the Government of India, Department of Industrial Policy & Promotion (DIPP).

The report was produced by UNIDO's department of Trade, Investment and Innovation (TII), under the directorship of Dr. Bernardo Calzadilla-Sarmiento, the project being managed by Dr. Anders Isaksson.

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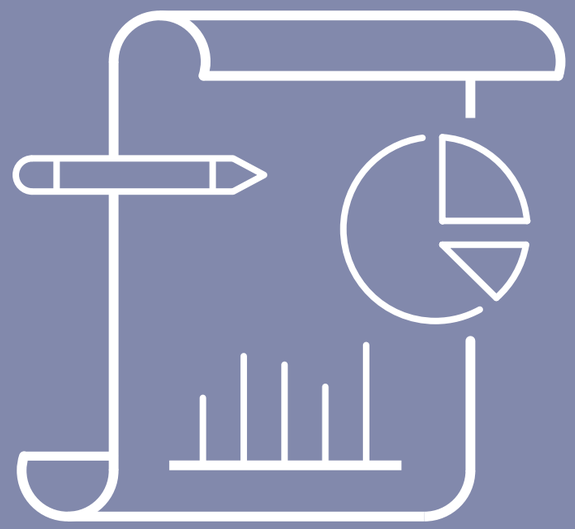
Proof reading was undertaken by Ms. Lauren Cooke, and final layout and Design was undertaken by Mr. Mauricio Mondragon and Ms. Maria Grineva.

Furthermore, we would like to extend thanks to the staff of the National Council for Cement and Building Materials (NCCBM) and the Cement Manufacturers' Association (CMA), in particular Mr. Sanjeev Kumar Chaturvedi and Mr. Shailendra Chouksey, respectively, for availing the necessary logistical support for the hosting of technical workshops and seminars, for support in data collection and active participation in the project.



EXECUTIVE SUMMARY

UNIDO has implemented a project titled 'Development and adoption of appropriate technologies for enhancing productivity in the cement sector', in collaboration with the Department of Industrial Policy and Promotion (DIPP), Ministry of Commerce and Industry, Government of India.

Under the aegis of the UNIDO International Centre for Inclusive and Sustainable Industrial Development (IC-ISID), New Delhi, the cement project aimed to support the Indian cement sector by strengthening the capacity and capability of the nodal technical institution for the sector – the National Council for Cement and Building Materials (NCCBM) - to provide management and technical support to the cement industry. The project looked to facilitate structured expert dialogue, transfer state-of-the-art technologies, and action a wide range of technical capacity building and knowledge sharing activities, and ultimately strengthen the global competitiveness of the Indian cement sector.

To fulfil this objective, one of the activities of the project was to conduct technical workshops for the scientists and engineers of NCCBM in areas such as energy usage and energy efficient solutions, waste derived fuels, CO_2 emissions and green technologies, patents and Intellectual Property Rights (IPRs), global best practices and up-to-date technologies.

One of the six workshops organised in this direction was on "Alternative Fuel and Alternative Raw Material" (AF/ARM), conducted on 7-9 June 2016. This technical report highlights the training provided with respect to the use of alternative fuels and alternative raw materials within the Indian cement sector. It covers the various aspects of co-processing, including international trends, waste regulation, types of AF/ARM, preprocessing, health and safety, AF/ARM management and incoming controls, sampling, preparation and analyses and the impact of AF/ARM on raw mix design and clinker reactivity. The report also covers the status of AF utilization in India, as presented by NCCBM staff during the workshop. The report concludes with an evaluation of NCCBM's abilities and knowledge base in different operations related to AF/ARM, as well as the nature of services that NCCBM could offer to the industry as a service company to a) waste generators, b) cement companies and c) the government to facilitate AF/ARM utilization.

As a result of the workshop, it was concluded that AF/ARM is a high-interest area for NCCBM, and that the organization has a key role to play for the technical development and adaptation of AF/ARM within the cement sector in India.

1 INTRODUCTION

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The project aimed to facilitate structured expert dialogue, transfer of state-of-the-art technologies to the Indian cement sector, and a wide range of technical capacity-building and knowledge sharing activities to boost the technical and managerial capabilities of NCCBM and ultimately strengthen the global competitiveness of the Indian cement sector.

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One of the six workshops organised in this direction was on "Alternative Fuel and Alternative Raw Material" (AF/ARM), conducted on 7-9 June 2016.

There is great potential for the development of alternative fuels and raw materials in India. This usage of AF/ARM would improve the competitiveness of the sector and will also help the local industries and the communities to manage their waste in a more sustainable manner. Thus, the topic represented a key area for the NCCBM, as cement companies would need support to develop and speed up the usage of alternative resources in their plants.

This topic must be managed from different perspectives. From a purely technical point of view, the AF/ARM impact on the clinker process as well as solutions to guarantee the compliance of the waste characteristics to specifications of the plants must be managed properly. Besides the technical approach, other elements must be included in order to bring the best chance of success to a given project, such as regulation and its implementation, communication, etc.

At the outset, the introduction of wastes may be considered a simple operation; however, a lot of skills must be integrated to make a project a success. A solid, scientific and technical background, such as in the NCCBM, is mandatory to make the AF/ARM usage sustainable with a global approach.

1.1. Objectives of the workshop

The objectives of the workshop were to:

1. Provide information about AF/ARM co-processing

This workshop provided a global picture about what AF/ARM co-processing means in a cement kiln, from the waste market to the impact on the process.

2. Identify potential gaps

Through the NCCBM presentations and group work, the training needs were identified and different approaches for the positioning of the NCCBM in this field were proposed.

The report is structured as follows:

» Chapter 1 provides an introduction and lists the objectives of the workshop.

» Chapter 2 covers the key aspects of AF/ARM co processing.

» Chapter 3 describes strategies for adopting AF/ARM and implementing projects.

» Chapter 4 provides a summary of the presentations made by NCCBM regarding the status of AF/ARM in India.

» Chapter 5 presents a synthesis of the interactions of the working groups, regarding the potential involvement of the NCCBM in different AF/ARM operations.

» Chapter 6 summarises the workshop participants' feedback.

» Chapter 7 describes possible options for positioning of the NCCBM in the AF/ARM field.

» Chapter 8 lists the main conclusions deduced after the workshop.

> "The project aimed to facilitate structured expert dialogue, transfer of state-of-the-art technologies to the Indian cement sector, and a wide range of technical capacity-building and knowledge sharing activities to boost the technical and managerial capabilities of NCCBM and ultimately strengthen the global competitiveness of the Indian cement sector."

AF/ARM CO-PROCESSING

2

2.1. Introduction

The presentations included: regulation; waste market and potential waste segments usable in co-processing; the preparation of AF out of wastes; health and safety management; the control of AF/ARM and the impact on the process and the clinker quality.

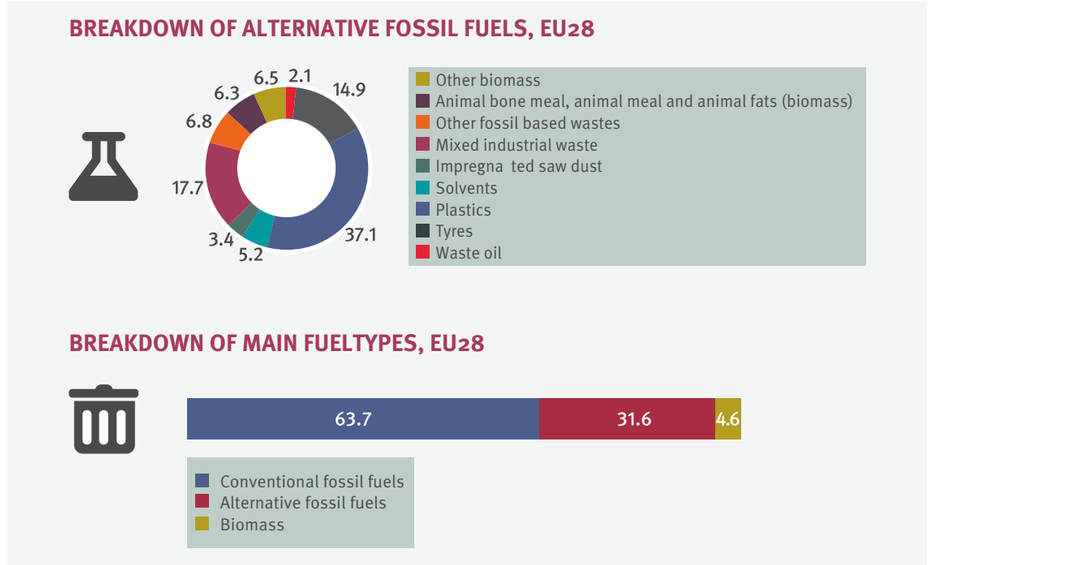
This part of the report must be read with the slides, which are attached.

2.2. International trends and reference studies

This section presents the status of state-of-the-art waste co-processing worldwide.

Co-processing started at the end of the 1970's in Europe and North-America and has since been developed in many countries worldwide.

Figure 1: Breakdown of alternative fossil fuels



The cement companies support the development of co-processing through guidelines issued by the Cement Sustainability Initiative (CSI) part of WBCSD.

Co-processing is recognized by a lot of countries. In Europe, co-processing is considered as a Best Available Technology (BAT) described in a (BREF) guideline. The Basel Convention (UNEP) has issued guidelines for co-processing.

Several scientific and technical surveys have been conducted to qualify the efficiency of co-processing in the cement process:

» Regarding environmental efficiency

» Regarding the material efficiency.

Worldwide, several cement plants are nearing a Thermal Substitution Rate (TSR) of close to 100%. Twenty-eight European countries have a TSR above 30%, with a continuous increase, and some are above 50% TSR, such as Germany and Austria. However, worldwide, the average TSR is about 15%.

The high substitution rates are achieved with a fuel mix made of different AF. This mix of fuels is done due to the large quantities required by a cement plant compared to the local availabilities, and also because the fuel selection is required to meet the constraints of co-processing. This diversification of the sources is also an important point to secure sourcing and avoid the dependency with one specific waste stream.

Regarding ARM, there are some cases of cement plants reaching 30% substitution rate in the raw mix. This high substitution rate is achieved in countries with strict regulations about landfilling, including soil from civil works.

In Europe, the substitution rate is about 5% representing about 6 million tons of wastes, mainly silica-wastes such as foundry sands or iron-wastes such as slag; mainly the wastes are a mixture of sources of aluminum, silica and iron.

2.3. Waste regulation and introduction to permitting

This section presents the evolution of waste regulation from the first to last steps, promoting the concept of circular economy and optimization of resource management.

Regulation is a key point in the creation of the waste market. The environmental conditions of an activity are defined by the regulations, but they also give an orientation to the waste streams, which means some disposal solutions are banned or over-taxed; some others are supported by exemption of taxes or subsidies.

Two keys concepts are highlighted:

» Circular Economy:

- This concept considers the resources management as a loop, meaning the wastes produced by one activity should become a resource for another activity.
- This concept is easily applied to co-processing, due to the replacement of fossil fuel and raw material by wastes.
- In addition, the cement plant offers a service to the waste producer creating a new activity within the cement sector.

» The Enlarged Responsibility of the Producers (ERP):

- This concept transfers the responsibility of the waste management to the producers of any goods, meaning the management of the end-of-life of any product must be managed as the product arrives in the market.
- This concept introduces/creates new entities for cement companies to partner with. This concept also creates the technical and economic conditions for a sustainable management of the wastes.

2.4. The different AF/ARM

This section presents the different wastes that can be used in co-processing to describe the following information:

» Origin

» Traditional disposal

» Supply chain

» Health and Environmental risks

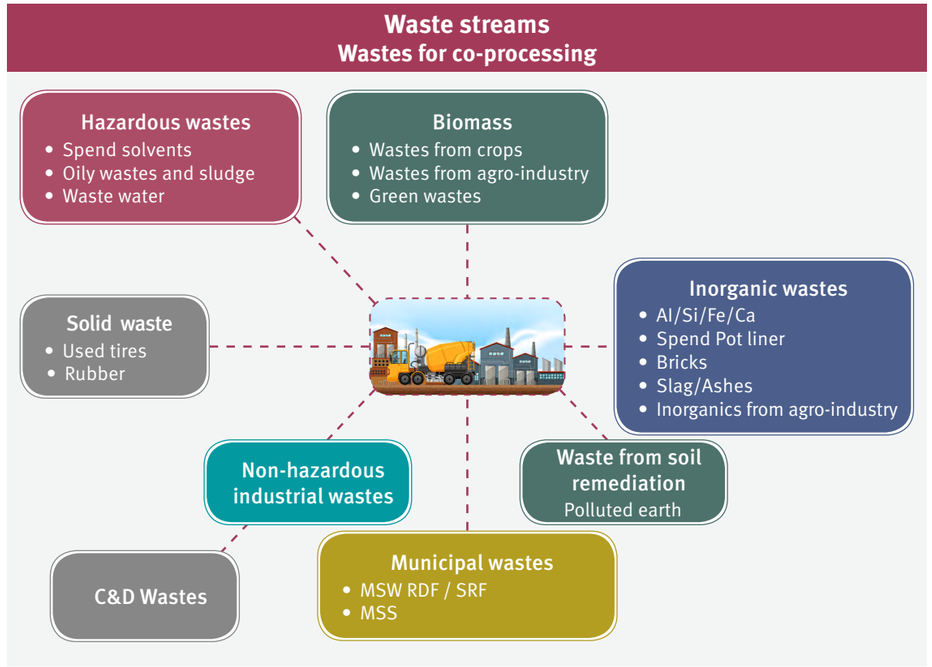
» Standard specifications and representative parameters

» Pre-processing technologies

» Capex and Opex

» Barriers to usage and development

Figure 2: Wastes for co-processing



The first waste streams in Europe and North America were hazardous wastes. They were used because of the similarity in their characteristics with fossil fuels, and the necessity for the waste generators to find a safe output for the hazardous waste. However, the new technology used in the industrial processes has reduced the quantity available of such waste.

Then, cement plants moved to solid waste such as used tyres and biomasses. The usage of biomass must be managed properly taking into consideration the potential competition with the production of food. As a consequence, the cement companies focus more on wastes from crops or agro-industries. Some potential cooperation with stakeholders has been described. Another way in which biomass is used is for the production of heat or power, introducing volatility to the price and often making biomass too expensive compared to traditional fossil fuels.

Recently, cement plants have entered into the municipal waste market, the Municipal Solid Wastes (MSW) and sewage sludge. The potential is huge in all the countries, but a preparation step is mandatory to produce AF compliant with co-processing.

Parallel to energy substitution, cement companies have been looking for alternatives to the raw material extracted from quarries. The raw mix of the clinker process is made from a balanced composition of different inorganics. Cement plants have been looking for alternative sources of alumina, silica, iron and limestone. Alumina was the first one to be sourced from the waste market.

The heterogeneity of the ARM that could be found in the waste market has been a limiting factor. Some waste introduces other minerals, which was destroying the normal chemical balance of the raw mix.

Detailed information in the section 2.9.2.

The figure 1 above presents the different waste streams used in cement plants worldwide.

The potential wastes usable in cement plants come from a lot of sectors: industrial activities; recycling activities; cleaning activities and the communities.

Solvents

» Chemical and pharmaceutical industries

» Painting and building material productions

» Cleaning activities in metallic workshop or garage

» Recycling activities

Used oils and industrial oils

» Any engine requiring lubrication (trucks, cars, power generator, etc.)

» Industrial processes (steel production, tire manufacture, food oil production, etc.)

» Recycling activities

Waste water

» Liquid wastes coming from economic activities such as: chemical and pharmaceutical processes

» Metallic workshops

» Airport (de-icing) and road activities

» Cleaning activities in industries

Industrial sludge

» Industrial sludge coming from treatment of all kinds of industrial effluents.

» Biological or physico-chemical sludge

» Tank, pipe or canal cleaning operations

» Inorganic sludge from aluminum products

Used tyres and rubber wastes

» Used tyres, tyre production and tire replacement

» Rubber wastes from recycling process

» Conveyor belts, production of shoes

Solid industrial wastes: non-hazardous and hazardous

» Packaging wastes

» Process wastes such as pulp wastes in recycling paper

» Off-spec products for product falls

» Packaging polluted with chemicals

» Inorganic industries: steel and aluminum industries, foundries, etc.

» Ashes from power plants

Municipal Solid Wastes (MSW)

» Municipal wastes are the wastes produced by citizen activities at home, in offices or in commercial areas.

Municipal Sewage sludge (MSS)

» Sewage sludge is produced by sewage plants treating municipal or industrial wastewaters.

Construction and Demolition Wastes (C&D)

» These wastes come from building works or building deconstruction

Biomass and green wastes

» Agricultural residues: Field base residues - stalks, straw, chicken litter, tops and leaves

» Process-based residues: husks, bagasse, glycerin, saw dust

The list of wastes available to the cement sector is long. The service offered by the cement plant differs depending upon the quality of the wastes. The price of the service must, at least take into consideration the potential impact on the clinker process to assure profitability to the operation, the specific investments related to the reception and the handling of the AF as well as all the costs related to the controls.

2.5. Preprocessing of waste to produce AF

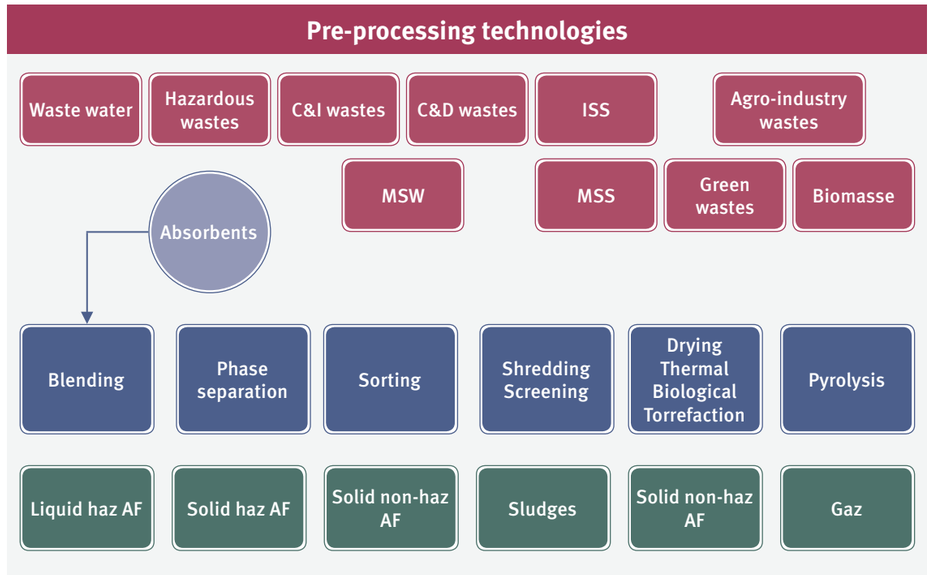
Many pre-processing technologies are used for the preparation of AF. They come from chemical activities or agro-industries.

The important factors to be considered for the usage of alternative fuels are:

The **homogeneity** of the AF is an important factor to keep a stable feeding to the kiln. The wastes are often a mixture of several components. Separation of phases and blending are two technologies that guarantee homogeneity.

The **physical aspect** of the AF is the second important factor in order to design the facility in the cement plant for the handling and

Figure 3: Pre-processing technologies



injection of the wastes. The waste could be liquid or solid but also pasty with very variable viscosity. Blending (dispersion) of solid in liquid or mixing of sludge with adsorbents is used to produce liquid or solid AF.

The **size of the particle** is the third important factor to define the injection point and the burning condition in the kiln. The waste could be very fine solid, big pieces, or a mixture of both. Shredding technologies have been developed as well as screening to guarantee homogeneity in particle size and define injection conditions.

Finally, the **moisture** is important to limit the impact on the process. The water content in the waste could be very high. Drying technologies are developing; biological using bacteria activity and thermal using external heat (or better still, the waste heat from the cement process).

The **Refuse Derived Fuel (RDF) or Solid Refuse Fuel (SRF)** production is a very promising activity for the cement sector. The sources are mainly the Municipal Solid Wastes (MSW), but also the non-hazardous wastes produced by the workshops and the industries, such as packaging and some process wastes.

Worldwide there are different solutions to approach the MSW market:

- A prudent approach by a very selective sorting of the MSW
- A more complete approach to target bigger quantities
- Or the concept of Mechanical Biological Treatment (MBT)

The economic parameters are also taken into consideration for the design of the preparation facility; the gate fee paid by the municipality is a key factor for the design of the investment and the profitability of the RDF in the cement plant.

The sorting operation is part of the process, by extracting the burnable fraction for RDF production but also the recyclables sold to the recycling activities making the RDF production.

The social aspect of this operation (mainly the sorting operation) must be well managed by the integration and improvement of the existing activities performed by scavengers.

2.6. Health and Safety AF/ARM

The focus on "Health and Safety" is set on risk assessment. The concept of risk assessment is based on a complete evaluation of the potential risks linked to a given activity. This concept could be applied to all sectors of activity, workshops etc. The contribution of the workshop management but also of the workers makes the exercise more exhaustive. An external consultant could help in some circumstances.

Risk management is crucial in all areas in order to minimize potential risks coming from AF/ ARM. An example of the different steps for risk assessment is in figure 4 below:

Figure 4: A H&S Risk Management system

A proper health and safety concept in laboratories must be a precondition prior to waste acceptance. The minimum requirements are:

- Sufficient ventilation and air condition (especially sample dryer)
- Fume hoods to be resistant against corrosive, harmful, toxic substances
- Fresh air supply for gas storage
- Gloves for harmful substances
- Safety glasses
- Masks for dusty substances (sample preparation)
- Separate laboratory for AF/ ARM analysis → no disturbance for routine production control and to avoid bacterial and hygienic contact

In the workshop, the health and safety management takes into consideration, the information provided by the waste generator and the information from the lab. The variability and the heterogeneity of the wastes is a factor in maximization of the risks. The mixing of different wastes must be managed properly as it is also a source of risk. Maintenance is also a source of risk, mainly when the normal maintenance team of the plant manages it.

The information about health and safety must be visible to anybody approaching the facility and an adapted training is mandatory to anybody working with AF, including truck drivers.

2.7. AF/ARM Management and incoming controls

AF/ ARM management concepts start with a target definition and the commitment to full compliance with the local regulations.

The plant team (all levels) must commit to protecting the health and safety of all employees, contractors and the local community. AF/ARM usage is done with respect for the environment and the guarantee of product quality to ensure customer satisfaction.

The common targets include:

- Appropriate waste quality controls (acceptance criteria and documentation)
- Appropriate operational controls (impact on process, product quality)
- Full transparency with stakeholders (communication plan internal & external)
- Organized plant operations (delivery, equipment maintenance, etc.)

AF/ ARM management consists of 3 distinct aspects in a cement plant:

1. Characterizing the material - Assessing the material, the supplier and any potential hazards associated with it.

2. Developing the specification - Risk of potential impacts from the use → include any applicable local standard.

3. Monitoring compliance – A control plan is developed to ensure that a material complies with the specification. To take into account the seriousness of meeting the specification requires defined actions (SOPs, documentation).

The frequency of sampling and analysis as incoming control is very much dependent on the following factors:

- Start with an assessment period (intense sampling & analyzing campaign to understand the material and its variability)
- Nature of the waste (is it hazardous?)
- Origin of the material (waste treatment plant, direct from supplier, etc.)
- Relation with supplier (Partnership, joint venture, simple contract agreement, etc.)
- Process and product sensitivity

To mitigate process disturbances and cement quality incidents, a solid AF/ ARM management system (including incoming control) must be developed including the following topics:

- Establish incoming material specifications
- Evaluate the risks
- Focus on specific key parameters that could have severe impacts and monitor them
- Evaluate the variability of material and adapt the sampling frequency
- Assure relevant lab and sampling method capabilities (AND lab capacities)
- Monitor and review regularly

The reception of waste in a cement plant is managed in 2 steps:

- A qualification procedure based on information provided by the customer (e.g. composition, quantities, variability, health and safety) and an analysis from a sample done by the dedicated cement plant or a third party.
- A reception procedure based on an administrative control of the delivery and a quality control on the waste delivered (analysis on representative parameters of the waste).

2.8. AF/ARM sampling, preparation and analyses

The sampling of the wastes, especially solid wastes, is the most difficult step to gain accurate information about its quality; this is valid for qualification, reception and operation.

Besides analyzing locations (own lab, centralized lab, supplier lab or third party lab) and sampling frequency, some other points must be taken into consideration.

- Sampling place: Where is the sample taken and for which purpose (truck, conveyor, dosing, etc.)
- Sampling type: automatic or manual (matter of investment), spot or composite, etc. Regardless of the choice, a multisampling of a truck or a regular sampling in the dosing system will limit the risk of mistakes.

A representative sample includes the sampling procedure and the sample preparation before introducing in the measurement equipment. The preparation step takes into consideration the physical aspects and the heterogeneity of the wastes. The sampling preparation for solids includes quartage operation and shredding. The preparation could require between 5 and 10 steps.

The qualification analysis includes maximum parameters to evaluate the risks and define the representative parameters of the waste. The reception analysis could be limited to the representative parameters, with some spot tests on other parameters.

Typical analyses for AF/ ARM are the calorific value, sulphur, chlorine, ash content, main element oxides, CHN, water content, flash point, PCB, heavy metals, etc.

Finally, the interpretation of an analytical result will take into consideration the sampling, the preparation and the potential interferences between different constituents of the waste.

2.9. AF/ARM Impact on raw mix design and clinker reactivity

The following aspects (characters, properties, conditions) can have an impact on the clinker reactivity.

An improvement of the clinker reactivity will show a positive impact on the cement performance.

As soon as the clinker reactivity is stable, an optimization of the SO_3 content is recommended. When the clinker reactivity varies the SO_3 content cannot be adapted. This will lead to problems with setting time and workability.

Figure 5: Phases of the reception of waste in cement plants

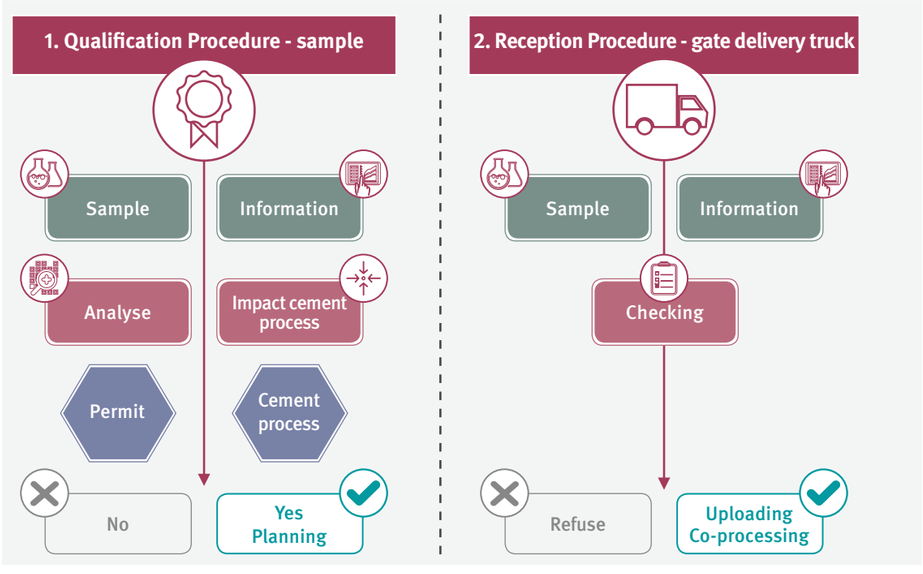
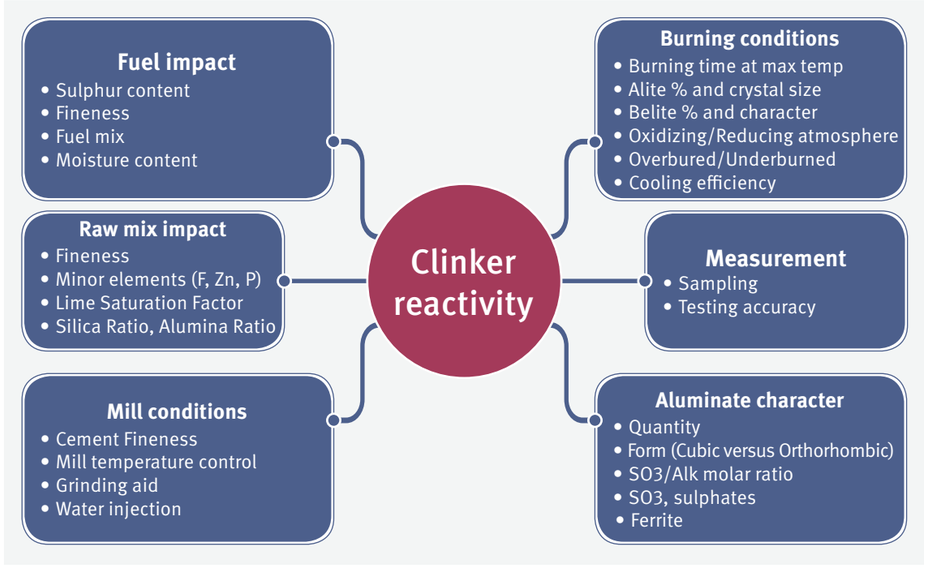


Figure 6: Clinker reactivity



2.9.1. AF Impact clinker reactivity

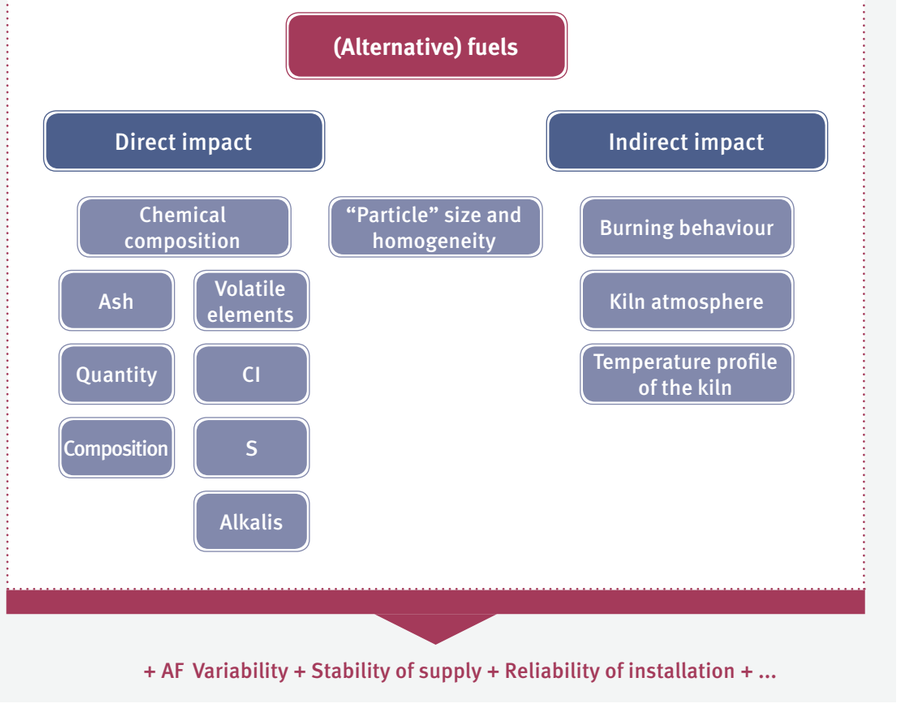
This section presents the use of Alternative Fuels (AFs) and their impact on the clinker reactivity.

The use of AFs to substitute or replace the natural fuels will change the clinker chemistry/ mineralogy due to the ash supplement. This can have both a positive or negative impact on the following:

One of the major risks is the failure of AF supply for reasons such as, very low stock, blockages in the dozing system, etc. There are no ways to correct the fuel mix accordingly or correct the raw meal. When the AF usage is not optimized (on the main burner) it can lead to reducing burning conditions (FeO, discoloration, setting time problems, etc.). Therefore, the following measures are recommended:

- Risk assessment (before using AF)
- AF specifications as an incoming control
- Proper measurements (control plan)
- Increase equipment reliability (maintenance plan)
- Clinker management (out of specification)
- Burning process optimization, development of SOPs
- Regular AF supply (contracts, follow up, etc.)

Figure 7: Direct and indirect impact of Alternative fuels on clinker reactivity



2.9.2. ARM impact on clinker reactivity and raw mix design

This section presents the use of Alternative Raw Materials (ARMs) and their impact on the raw mix design and on the clinker reactivity.

The use of ARMs to substitute the natural raw materials may change the proportions of the existing materials. This can have both, a positive or negative impact on the following:

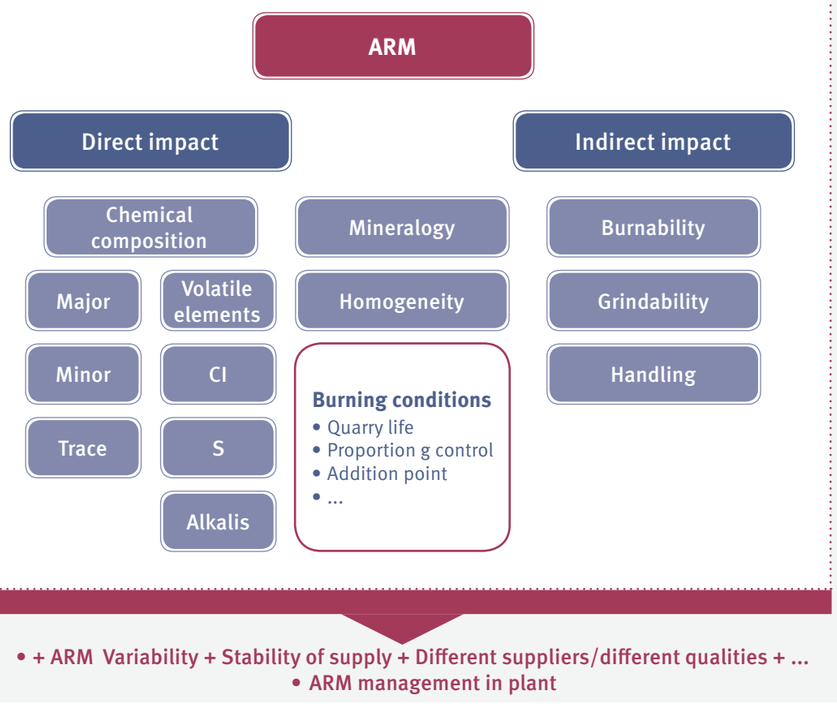
Alternative raw materials are divided into streams according to their type (e.g. sludge, ash, slag) and their major chemical oxides. Clinker chemistry is fairly restrictive for CaO, SiO_2, Al_2O_3 and Fe_2O_3 and therefore alternative materials should have a narrow range falling within the requirements. There are guidelines for acceptance of ARMs with regard to trace elements and heavy metals.

Typical ARM waste streams classified according to their type or chemistry are listed below.

Sludge

- **Alumina sludge**: Alumina rich sludge (H_2O ›30%: Al_2O_3 ›30%) including sludge from alumina hydroxide, stainless steel, ceramic, iron hydroxide and incinerator.
- **Sludge other**: All other sludge including those from silanes, iron hydroxide, CaF, ceramic, and water treatment.

Figure 8: Direct and indirect impact of ARM



Ash

» **Power plant ash**: Includes bottom ash, fly ash (wet or dry) from coal-fired, power generating facilities.

» **Ash other**: Include paper ash, incinerator ash, pulp and paper ash. It does not include pyrite ash.

Slag

» **All types**: All slags resulting from metal (ferrous, non-ferrous) refining. Includes iron, steel, convertor, blast furnace, granulated, pelletized, ground, zinc and copper materials.

Alumina

» **Alumina catalysts**: Includes FCC and iron catalyst with high alumina content.

» **Alumina bricks**: Includes alumina rich construction bricks, refractories, ceramics and tiles.

» **Alumina process waste**: Includes Oxiton, Al dross and SPL 2nd cut.

Iron

» **Mill scale, pyrite cinders**: Includes iron oxide, roasted pyrite and pyrite ash/cinders.

» **Red Mud**: Includes red mud and brown mud.

» **Iron other**: All other iron wastes: iron cake, steel dross, iron catalyst, iron fines, BOF dust, jarosite and goethite.

Calcium

» **Calcium, lime and other**: Includes dry CaF, waste limestone, lime dust and gypsum.

Silica

» **Foundry sand**: By-product of metal casting industry and casting cores.

» **Sandblast**: Includes abrasives and surface metal treatment.

» **Silica other**: Includes filtration media, silica fume, glass, and silica board.

Soil

» **Soils, street sweeping**: Included contaminated soil, street sweepings, waste stones and other dust.

2.10. Questions

During the course of the workshop, the participants from NCCBM asked a variety of questions. Some of the questions were:

» Questions about the waste description, for example which waste is considered as hazardous or non-hazardous?

» Questions about the positive (NOx reduction) and negative impact (introduction of moisture/impact of production ratio) on the process.

» Questions about the transport of wastes.

» Questions about the standards used in the AF/ARM sector (sampling, analysis).

» Questions about the technical solutions to reach high Thermal Substitution Rate (TSR)

» Questions (high interest) about the Municipal Solid Wastes (MSW); technical detail about the sorting, the RDF production and the different drying technologies.

Expert comments:

The workshop participants have mainly technical and scientific backgrounds; the economic aspects are not sufficiently integrated in the approach to the different problem areas.

AF/ARM STRATEGY AND PROJECTS 3

In a cement company, the adoption of an AF/ARM strategy starts with the clear commitment of top management. This commitment must be quantified after a clear detailed exploration of the potential of the market and the plant.

The exploration of the market with a mid and long- term vision will define the sourcing strategy including the positioning about pre-processing.

The exploration of the impact in each cement plant will define the potential savings but also the capital expenditure required for the waste facilities in the cement plant and the adaptation of the process and the plant.

The waste market approach as well as the technical specificities of the waste management requires specific skills. Most cement companies create dedicated companies or departments to manage those specificities.

The waste market is strongly influenced by regulation. Lobbying by waste companies, can facilitate the cement process specificities being recognized by regulation, and co-processing becoming fully integrated in the local waste management network.

(See figure 9 in the next page.)

AF/ARM projects are made of several operations:

» A **permitting procedure**: this procedure requires complete knowledge of the regulation along with the consequences on waste management and the environmental impact of the cement plant. The duration of the procedure could be a factor that delays starting a project.

» The **sourcing strategy** will be defined after an investigation of the market and the identification of the local opportunities. The project manager will have to define a potential integration of the pre-processing or a pure contractual approach.

» An AF/ARM project will invite questions from all the stakeholders, a pro-active **communication plan** will explain the project and will aim to keep a constant link between the plant and the stakeholders.

» The design of the facilities (co-processing and pre-processing) must integrate the variability of the wastes and the potential evolution of the market (high volatility of the waste market); a significant level of **flexibility** will bring a higher potential of profitability.

(See figure 10 in the next page.)

Figure 9: AF/ARM strategy

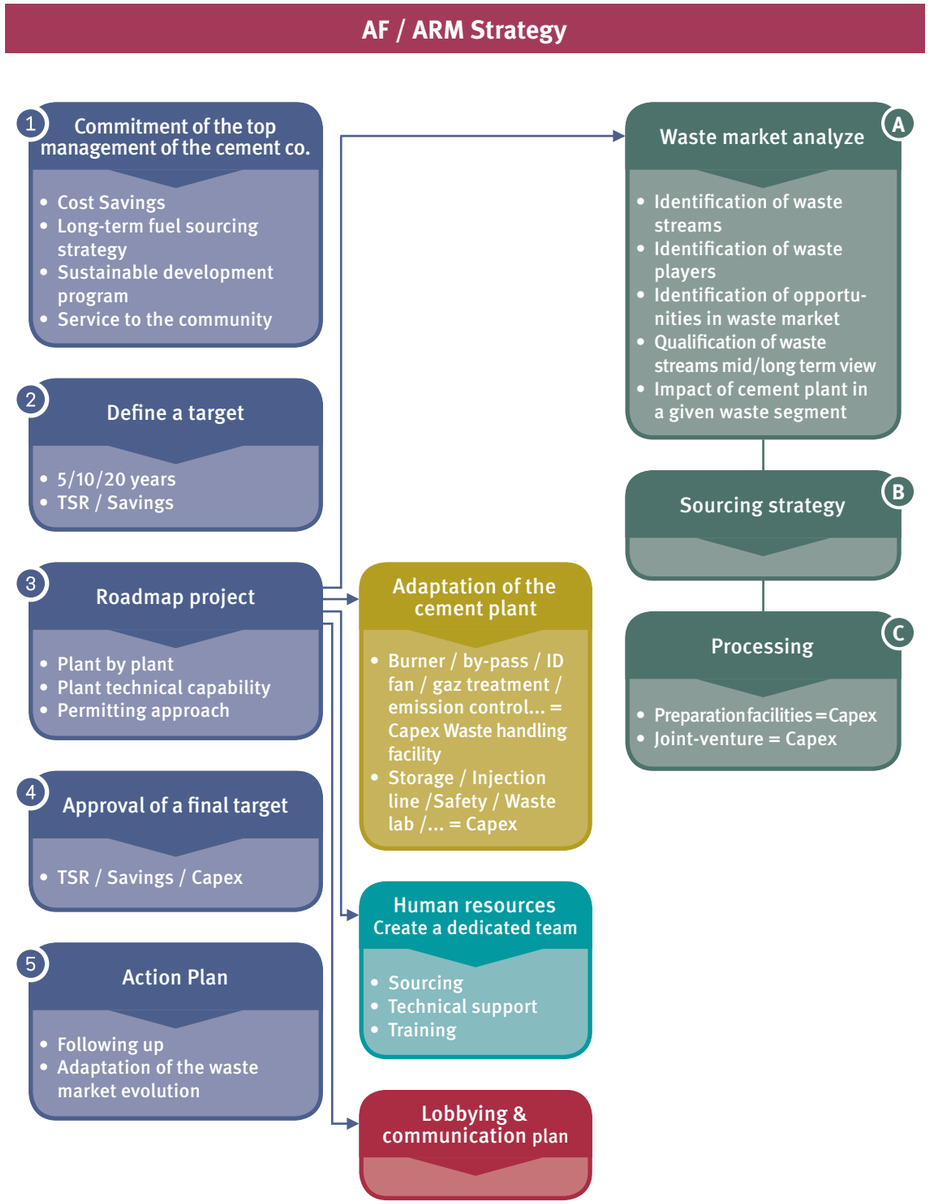
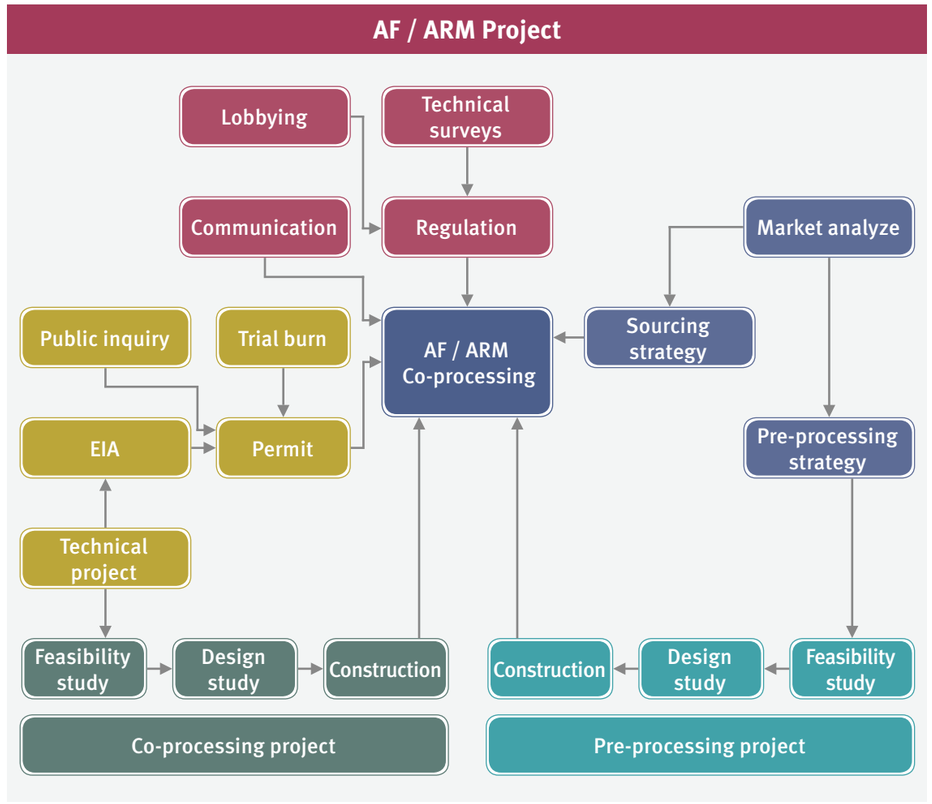


Figure 10: AF/ARM project



NCCBM PRESENTATIONS

4

4.1. Synthesis

The participants of the workshop were also requested to deliver short presentations regarding the Indian cement sector and various aspects of AF/ARM applicability. The following information was shared through the presentations made by NCCBM staff:

Waste market

The quantitative information shows that a huge quantity of biomass is produced in India and quite a large quantity is still available. But the calorific value is probably over-estimated. The potential TSR achievable with the available fraction of the market could be 15% (instead of 30% announced).

Considering the level of industrialization of India, the quantity of industrial (hazardous and non-hazardous) seems to be small.

The AF preparation sector seems to be very small but with huge potential for development.

Co-processing in India

The presentations showed a lot a trials and a lot of different waste streams that have been authorized by a permit. But the TSR quantities are very small except one case where one plant achieved 60% TSR.

Regulation

Co-processing seems to be recognized by the authorities; even CPCB has issued technical guidelines. The interpretation of local CPCB seems to be a problem, as well as the limitation of interstate transport of wastes.

The roadblocks for co-processing development

The NCCBM identified the following roadblocks:

- Technical: despite the fact that most of the cement plants are based on “new generation” processes, the design seems to be a limiting factor. Often there is too short a residence time in the calciner and not enough space in the layout. The operation in sold-out conditions reinforces the critical impact of the residence time.
- Knowledge: the compensation measures to limit the AF/ARM impact are not known.
- Economics: the gate fee for waste treatment in India is limited to some waste streams and close to zero for the most important part of the market.

NCCBM and co-processing

The NCCBM seems to have more experience in ARM than AF. The competencies in firing and combustion must be checked.

4.2. Comments[1]

Based on the presentations, the expert comments regarding the AF/ARM situation in India are as follows:

Co-processing is recognized in India as a solution for waste management but the interpretation by local authorities seems to limit the development as well as the free transport of wastes inside India.

An independent technical support that has an experimental approach would be useful to help the local authorities.

Co-processing exists in India; a lot of trial burns have been performed with a lot of different waste streams, AF and ARM.

A synthesis of the trial burn would be useful to the authorities and the cement sector to speed up the development of co-processing.

The AF preparation sector is not developed enough for 2 main reasons: the low gate fee for raw wastes and no long-term commitment from the cement sector. In parallel, the cement sector is probably asking for a quality that is too high.

The preparation sector needs economic support from:

- *A strict enforcement of regulations to avoid the low-cost waste treatment solution; and/or*
- *Subsidies for environmentally-friendly treatment solutions; and/or*
- *Long-term commitment from the cement sector vis-a-vis the waste preparation by integration or long-term contract.*

The sold-out situation of most of the cement plants and the low cost of fossil fuels are limiting the ambition of the cement plants and/or the cement plants are requesting a quality that is too high.

The cement sector needs technical support to disseminate the massive usage of AF. To overcome this situation, some investment will be required in the cement plant; for example: modification of calciner with a potential double impact to increase production and make the AF usage easier.

[1] Expert proposals are written in italics

WORKING GROUPS

5

The audience was divided into 4 groups of 4 people. Each group had to answer questions about the potential implications of the NCCBM in the different operations related to AF/ARM. The results presented are the result of a discussion in each group, facilitated by one presenter; each member could have a different opinion. The domain of competence of each member could have an influence on the overall opinion but each member had general information about the other departments.

The questionnaire is attached in Annex 1 and the following was noted for each topic:

» Answers of the NCCBM participants are summarized

» A coloured scale was developed to illustrate the participants' knowledge level (evaluated by the experts after the first workshop); the arrow shows the score[2].

[2] A summary of the participants' comments (NCCBM as well as experts) is provided in Italics.

5.1. Waste market survey

Fifteen/Sixteen participants expressed that this activity is not in the existing scope of the NCCBM (1 positive opinion related to ARM). It was also expressed that it should be included in the scope (by 15 out of the 16 participants). The competencies are not considered to be enough in the NCCBM (according to 7/16 participants) or only partly sufficient (according to 8/16 participants).

Summary

Approaching the waste generators seems to be a skill that must be imparted: at least soft skills for approaching customers and some marketing skills.

5.2. Bringing solutions to waste producers in cement plants

11/16 participants did not consider this activity to be included in the existing scope of NCCBM, and 15/16 participants expressed that it should be included for AF/ARM. It was also expressed that the competencies for this activity exist at the NCCBM by 5/16 participants; however, 7/16 participants felt that the existing competencies are not sufficient.

ARM

AF

Summary

The competencies regarding AF seem to be the most crucial need. Some of the participants expressed the need for a dedicated lab and specific department for interpretation of results and building solutions.

5.3. Define procedure for sampling and analysis

8/16 of the participants considered this activity to be fully within the scope of the NCCBM, while the other 8/16 considered it to be included partially. However, all participants agreed that it should be included in the scope of activities, and that the competencies for this activity partially exist at the NCCBM.

ARM

AF

Summary

Extending the competencies to AF seems to be the most crucial need. A lack of equipment has been identified. General training to update the skills has been requested.

5.4. Waste qualification

8/16 participants considered this activity to be within the NCCBM's scope of activities, while 4/16 participants considered to be only partially included. All participants agreed that it must be included in the NCCBM's scope of activities, and the competencies for this exist partially at present.

ARM

AF

Summary

The analytical competencies exist from a purely technical point of view. Training about the implementation of these competencies to the waste is required.

5.5. Reference cases

According to 12/16 participants, the creation of reference cases in terms of technologies for pre and co-processing is not in the scope of the NCCBM, and the remaining 4/16 participants expressed that it is only partly included. All participants agreed that it should be included completely. Half of the participants expressed that the required competencies exist at the NCCBM, while the other half felt that the competencies exist partially. 12/16 participants expressed that knowledge for pre-processing is partly available at the NCCBM.

All the participants expressed that the creation of reference cases, from an economic point of view, is not in the scope of the NCCBM, neither for pre-processing nor for co-processing, but should be there. According to half of the participants, competencies for co-processing are not fully given. For pre-processing, the competencies are not enough, according to 12/16 participants.

Technology pre-processing

Economic pre-processing

Technology co-processing

Economic co-processing

Summary: *The NCCBM workshop participants highlighted the need for more detailed training with reference cases and best practices.*

5.6. Manage or support pilot projects

According to 12/16 participants, this activity is mainly not in the scope and should be included. 4/16 participants expressed that the competencies are given at NCCBM, another 4/16 participants expressed that competencies existed partially, and the remaining felt that these competencies do not exist at all. This shows dissimilarity in the answers of different department representatives.

Summary

The NCCBM employees highlighted the need for more hands-on training and visits to different sights.

5.7. Environmental Impact Assessment (EIA)

All 16 participants considered this activity to be in the scope of the NCCBM. 50% of the participants have full competencies and the other 50% need further training especially on AF/ ARM topics.

Summary

The last full EIA was done about 10 years ago. The expertise is low as most of the workshop participants have only been in the NCCBM organization a few years.

5.8. Opportunity and feasibility studies

For 8/16 participants, this activity is in the scope of NCCBM, and the other half expressed that it is not fully included, but should be included. Half of the participants expressed that the competencies for this activity exist for most of the participants, but for the ones who don't have the competencies at all.

Summary

The identified needs are related to the upgrading of the cement plant from a basic cement plant operation to AF/ ARM usage. The needs are to develop more intense project management skills and the knowledge of the best technologies available.

5.9. Design of projects and follow up

Most of the participants (12/16 participants) are of the opinion that the activity "Design of facilities" is not in the scope of the NCCBM but should be included. The competencies are given for a routine cement plant, but not for the usage of AF/ ARM. Technical tools like Autocad, 3D modelling software, etc. are available in the NCCBM.

All participants agreed that the follow up of projects is clearly in the scope of the NCCBM, and that the competencies are partly given.

Plant support activity was also considered to be in the scope of the NCCBM by all 16 participants. 9/16 participants felt that the competencies for this are mostly given.

Summary

The need is linked to the youngest community who need more experience in the follow up of projects.

5.10. Risk assessment

The question related to risk assessment shows discrepancies within the 16 participants: 50% are sure it is inside the scope, 50% disagree. 4/16 participants expressed that the competencies for this exist partly, while 8/16 felt that they do not exist at all.

Summary

An upgrade and strengthening of the NCCBM knowledge is necessary (e.g. real case examples, toolbox, guidelines, etc.)

5.11. Dissemination of technologies

This activity is considered as included in the existing scope of the NCCBM by all 16 participants. Most of the participants are of the opinion that NCCBM has the competencies fully (9/16 participants) or partly (4/16 participants). The NCCBM informs industry regularly through seminars, newsletters and hosts the best platform in India.

6 FEEDBACK FROM PARTICIPANTS

The audience was asked to fill out a standard UNIDO feedback form. In addition, another page was attached in order to understand the 19 participants' needs. They could select per topic if there was a "strong need" or "need" for additional knowledge, if they "have sufficient knowledge" or if they don't need any additional support.

In general, the feedback shows a high interest from the participants; their motivation is very strong and they are ready to get involved with the topic details.

In some cases, there is a "strong need" for additional knowledge. In most cases, some basics exist and the participants show the "need" for more knowhow, best practices, etc.

The percentage of the NCCBM employees who feel fully confident with the topics is mainly below 10% (except XRD Rietveld analysis).

Table 1: Feedback from participants

Topics	"Strong need" for additional knowledge (%)	"Need" for additional knowledge (%)	"Have suffiecient knowledge" (%)	"No need" for additional knowledge (%)
International trends	39	56	6	0
Waste regulation	33	61	6	0
Plant capabilities to use AF / ARM	16	79	5	0
Preprocessing of waste to produce AF	44	50	6	0
AF / ARM management and incoming control	32	58	11	0
AF / ARM sampling preparation and analysis	47	47	5	0
AF / ARM impact on raw mix design and clinker reactivity	17	78	6	0
XRD Rietveld analysis	41	41	18	0
How to conduct an AF / ARM project	28	61	11	0

POSITIONING OF THE NCCBM IN THE AF/ARM FIELD

7

Considering the AF/ARM co-processing in cement plants, the NCCBM should be positioned:

1. As a service company to waste generators offering the following:

» Analysis of wastes

» Feasibility for co-processing

These services should be financed by the waste generator.

2. As a service to cement companies offering the following:

» Waste analysis (qualification processes)

» Environmental Impact Assessment

» Support to project development

» Analysis of incidents and roadblocks, remediation plan

» Support to Risk Assessment Study

Elaboration of Standard Operation Procedure (SOP)

These services should be financed by the cement companies

3. As a service to government (national and local)

» Technical support to authorities (technical lobbying)

» Redaction of technical notes for local authorities (technical enforcement of regulation)

» Waste stock exchange (online platform hosted by the NCCBM)

» Update of Guidelines for co-processing with the concept of Best Available Technology. Example: the EU has created a Join Research Centre (website JRC@eu), which is a technical tool for European Regulation.

» Technical expert for pilot projects (in case the government decides to subsidize project)

» Reference centre

» Reference cases in co-processing

» Reference case in pre-processing (questionable?)

These activities should be financed by DIPP/CPCB

Positioning of the NCCBM in the AF/ARM field

The activities described above should be managed by different departments or services:

» A dedicated department for technical support to co-processing working on reference cases, supporting the pilot projects, providing technical support to the authorities (local/state and federal) and managing a waste stock exchange.

» A dedicated department (including a lab) for waste sampling and analysis with equipment and skills for interpretation of results; this department should have the ability to give recommendations in terms of co-processing feasibility of a given waste stream.

» A service team for AF/ARM project management, targeting mainly SMEs, providing the big companies have their own competencies for the management of projects.

The case of pre-processing is much more complex because the NCCBM is starting from scratch in this field. The MSW case should be treated separately considering the potential for development. This topic should be managed in cooperation with a waste management association or research centre about waste.

8 CONCLUSION

The workshop participants showed strong motivation and interest in the topic of AF/ARM. The presentations highlighted the huge potential for progress in this field in India, but the need for knowledge and expertise is clearly identified.

The NCCBM should play different roles in this development, due to the scientific level of the structure and the strong willingness of each of the employees.

The development of AF/ARM co-processing is a combination of: regulation enforcement; technical development and adaptation; and commitment by the waste management sector as well as the cement sector. To start the initial push and consolidate the development of co-processing, a strong involvement by the public authorities is a key factor in order to create the waste market and to make co-processing a sustainable solution for waste management.

The connection of the NCCBM to the public authorities (DIPP) as well as the cement sector places the NCCBM in a strategic position to promote this new activity within safe and sustainable conditions. Organizational options are proposed in this report. The need for training is also clearly identified.

Considering the questions from the audience, a second workshop focused on the preparation of RDF/SRF out of MSW, with a detailed approach of the technology and the economics of a project would be welcomed.

NCCBM is also keen on receiving support in terms of lobbying to give recommendations about regulation and market availability.

ANNEXES

Annex 1: Questionnaire

The following questions were tackled during the AF/ ARM workshop:

#	Question
1	Waste market analysis
2	Solutions provided to waste producers in cement plants
3	Define procedures for sampling and analysis
4	Waste qualification (sampling/analysis)
5	Create reference cases in co-processing (technologies)
6	Create reference cases in co-processing (economics)
7	Create reference cases in pre-processing (technologies)
8	Create reference cases in pre-processing (economics)
9	Management or support to pilot projects
10	Environmental Impact Assessment
11	Opportunity/Feasibility studies of projects (in cement plant/in pre-processing)
12	Design of facilities (in cement plant/ in pre-processing)
13	Follow up of projects
14	Support to plant (analyze problems/propose solutions)
15	Risk assessment of facilities or operations
16	Dissemination of Best Available Technologies

Annex 2: Evaluation of the NCCBM positioning in the AF/ARM activities

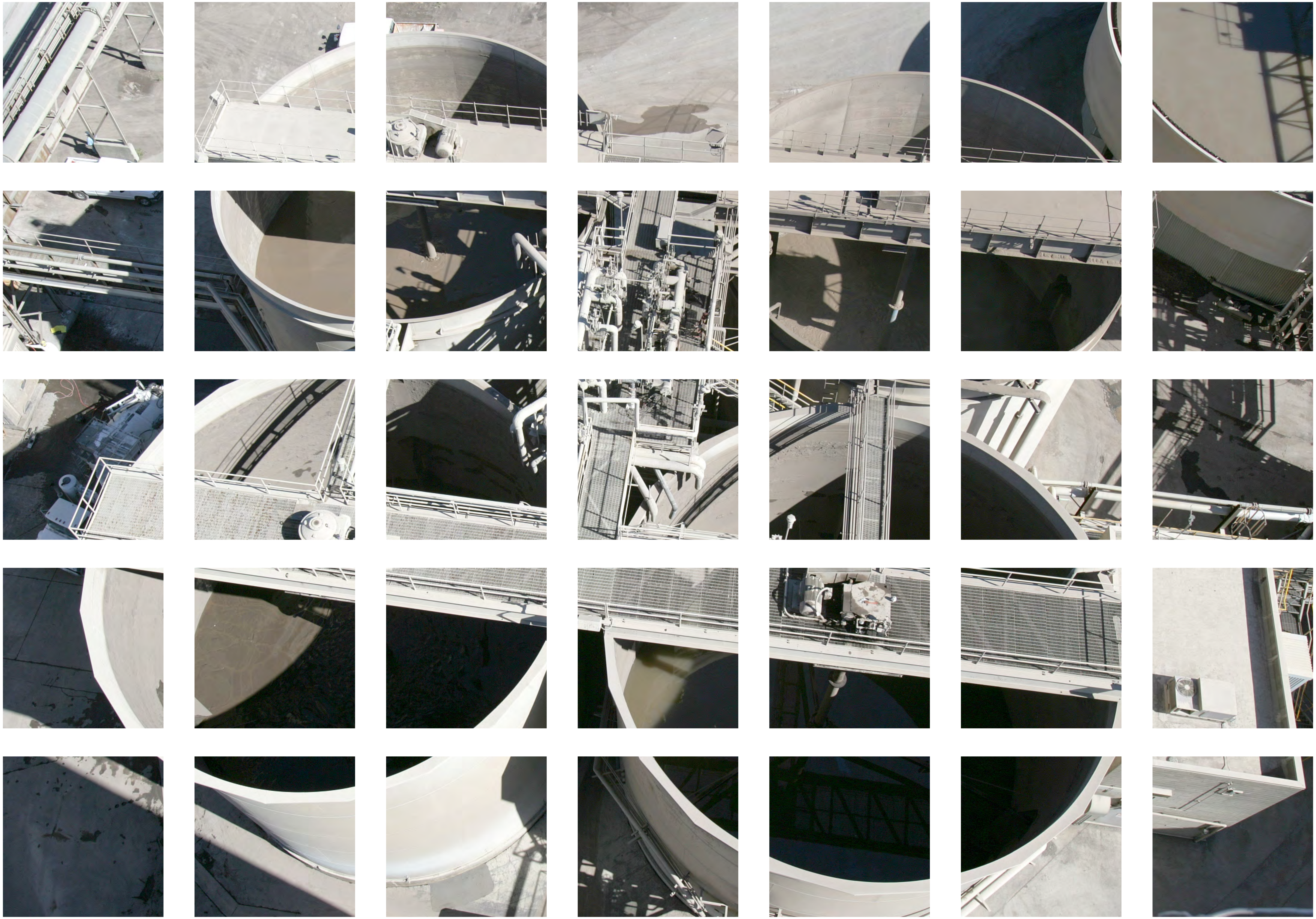
Topics	Inside the existing NCCBM Scope			To be added to NCCBM scope		Competences in NCCBM			If no, how to get the competencies ?
	Yes	Partly	No	Yes	No	Yes	Partly	No	
Waste market analyze Group 1			4	4			4		No marketing people are present in NCCBM. Business models to be provided
Waste market analyze Group 2			4	4				4	Training required
Waste market analyze Group 3			4	4			4		Soft skilled for customer approachs
Waste market analyze Group 4	1		3	3	1	1		3	
Waste market analyze total	**1**		**15**	**15**	**1**	**1**	**8**	**7**	
Bringing solution to waste producers in cement plants Group 1		4		4			4		Training to be provided (ARM is inside NCCBM scope, AF not)
Bringing solution to waste producers in cement plants Group 2			4	4				4	Training required
Bringing solution to waste producers in cement plants Group 3			4	4		4			Separate lab AF and department Interpretation skill 2 studies/year
Bringing solution to waste producers in cement plants Group 4	1		3	3	1	1		3	Already negotiations with steel industry, copper; competencies on solutions for AF (how to approach negotiations, examples with specifications like CIZ)
Bringing solution to waste producers in cement plants total	**1**	**4**	**11**	**15**	**1**	**5**	**4**	**7**	
Define procedures for sampling and analyze Group 1		4		4			4		Need training for AF. Need additional equipment and training to complete portfolio of testing capability (for ARM it is done and OK)
Define procedures for sampling and analyze Group 2		4		4			4		Partially available/training required/equipment required
Define procedures for sampling and analyze Group 3	4				4		4		Need some training for development of the missing ones
Define procedures for sampling and analyze Group 4	4				4		4		partly: for AF/ ARMx
Define procedures for sampling and analyze total	**8**	**8**		**8**	**8**		**16**		

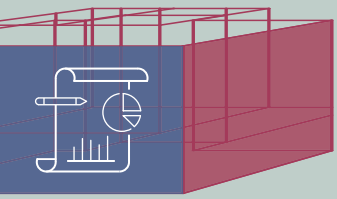
Topics	Inside the existing NCCBM Scope			To be added to NCCBM scope		Competences in NCCBM			If no, how to get the competencies ?
	Yes	Partly	No	Yes	No	Yes	Partly	No	
Making waste qualification (sampling/analyzes/...) Group 1			4	4			4		Analytical competency is OK; need competency mainly for the qualification of waste, Training of sampling AF required
Making waste qualification (sampling/analyzes/...) Group 2		4		4			4		Partially available/training required
Making waste qualification (sampling/analyzes/...) Group 3	4				4		4		Need some training for development of the missing ones
Making waste qualification (sampling/analyzes/...) Group 4	4				4		4		more intensive training required
Making waste qualification (sampling/analyzes/...) total	**8**	**4**	**4**	**8**	**8**		**16**		
Create reference cases in co-processing (technologies) Group 1		4		4			4		
Create reference cases in co-processing (technologies) Group 2			4	4		4			
Create reference cases in co-processing (technologies) Group 3			4	4		4			Updating training
Create reference cases in co-processing (technologies) Group 4			4	4			4		detailed training, example reference cases, best practices
Create reference cases in co-processing (technologies) total		**4**	**12**	**16**		**8**	**8**		
Create reference cases in co-processing (economics) Group 1			4	4				4	
Create reference cases in co-processing (economics) Group 2			4	4				4	
Create reference cases in co-processing (economics) Group 3			4	4			4		To be completed
Create reference cases in co-processing (economics) Group 4			4	4			4		detailed training, example reference cases, best practices
Create reference cases in co-processing (economics) total			**16**	**16**			**8**	**8**	
Create reference cases in pre-processing (technologies) Group 1		4		4			4		
Create reference cases in pre-processing (technologies) Group 2			4	4				4	
Create reference cases in pre-processing (technologies) Group 3			4	4			4		Some basics, to be completed.
Create reference cases in pre-processing (technologies) Group 4			4	4			4		detailed training, example reference cases, best practices
Create reference cases in pre-processing (technologies) total		**4**	**12**	**16**			**12**	**4**	

Topics	Inside the existing NCCBM Scope			To be added to NCCBM scope		Competences in NCCBM			If no, how to get the competencies ?
	Yes	Partly	No	Yes	No	Yes	Partly	No	
Create reference cases in pre-processing economics) Group 1			4	4				4	
Create reference cases in pre-processing economics) Group 2			4	4				4	
Create reference cases in pre-processing economics) Group 3			4	4				4	Training on-job training
Create reference cases in pre-processing economics) Group 4			4	4			4		detailed training, example reference cases, best practices
Create reference cases in pre-processing economics) total			**16**	**16**			**4**	**12**	
Management or support to pilot projects Group 1	4				4		4		Process engineers competent
Management or support to pilot projects Group 2			4	4				4	
Management or support to pilot projects Group 3			4	4		4			pilot existing in NCB but problem of Capex
Management or support to pilot projects Group 4			4	4				4	hands on training, visits to sights
Management or support to pilot projects total	**4**		**12**	**12**	**4**	**4**	**4**	**8**	
Environmental Impact Assessment Group 1	4				4	4			Need additional equipment (D/F analysis)
Environmental Impact Assessment Group 2	4				4		4		Partially availiable/to be strengthened
Environmental Impact Assessment Group 3	4				4	4			
Environmental Impact Assessment Group 4	4				4			4	need experiences for larger project, especially for waste fuels (they are doing for routine cement topics) ... 10years ago was the last full EIA ... now it is only a "small" follow up, training needed for AF/ ARM
Environmental Impact Assessment total	**16**				**16**	**8**	**4**	**4**	
Opportunity/Feasibility studies of projects (In cement plant/in pre-processing) Group 1	4				4	4			
Opportunity/Feasibility studies of projects (In cement plant/in pre-processing) Group 2	4				4	4			to be strenghened
Opportunity/Feasibility studies of projects (In cement plant/in pre-processing) Group 3		4		4			4		Cement plant is clear, upgrading from goundfloor for pre-processing
Opportunity/Feasibility studies of projects (In cement plant/in pre-processing) Group 4			4	4				4	project management and sight visits, best technology knowledge
Opportunity/Feasibility studies of projects (In cement plant/in preprocessing) total	**8**	**4**	**4**	**8**	**8**	**8**	**4**	**4**	

Topics	Inside the existing NCCBM Scope			To be added to NCCBM scope		Competences in NCCBM			If no, how to get the competencies ?
	Yes	Partly	No	Yes	No	Yes	Partly	No	
Design of facilities (in cement plant/ in preprocessing) Group 1	4				4		4		Have Autocad, need 3D modelling software
Design of facilities (in cement plant/ in preprocessing) Group 2			4	4			4		to be strengthened
Design of facilities (in cement plant/ in preprocessing) Group 3			4	4				4	Training on-job training design concept
Design of facilities (in cement plant/ in preprocessing) Group 4			4	4				4	for routine cement plants it is ok, for AF/ ARM the gap is very large
Design of facilities (in cement plant/ in preprocessing) total	**4**		**12**	**12**	**4**		**8**	**8**	
Follow up of projects Group 1	4				4	4			
Follow up of projects Group 2	4				4			4	
Follow up of projects Group 3	4				4		4		Need to have training
Follow up of projects Group 4	4				4		4		up to now there were no projects to follow up
Follow up of projects total	**16**				**16**	**4**	**8**	**4**	
Support to plant (analyze problems/propose solutions) Group 1	4				4	4			200 plants are producing 97% of the capacity. NCCBM target these plants for Plant support. Ultratech (9omt) have own testing research capacity BUT need to use NCCBM to change any National approval
Support to plant (analyze problems/propose solutions) Group 2	4				4		4		
Support to plant (analyze problems/propose solutions) Group 3	4				4	4			3/4 problems has been solved per year
Support to plant (analyze problems/propose solutions) Group 4	4				4	1		3	Only select staff are involved in raw mix design, process, kiln stability, product quality, etc, working with KPIs.
Support to plant (analyze problems/propose solutions) total	**16**				**16**	**9**	**4**	**3**	
Risk assessment of facilities or operations Group 1			4	4				4	Would like a 'toolbox' or guidelines how to structure this.
Risk assessment of facilities or operations Group 2	4				4		4		Partially available
Risk assessment of facilities or operations Group 3	4				4	4			Upgrading required
Risk assessment of facilities or operations Group 4			4	4				4	real case example, detailed training necessary
Risk assessment of facilities or operations total	**8**		**8**	**8**	**8**	**4**	**4**	**8**	

Topics	Inside the existing NCCBM Scope			To be added to NCCBM scope		Competences in NCCBM			If no, how to get the competencies ?
	Yes	Partly	No	Yes	No	Yes	Partly	No	
Dissemination of Best Available Technologies Group 1	4				4	4			NCCBM opinion is that they diseminate information through Seminars, Newsletters etc.
Dissemination of Best Available Technologies Group 2	4				4		4		NCB is the best platform/ training required
Dissemination of Best Available Technologies Group 3	4				4	4			Revise the dissemination means
Dissemination of Best Available Technologies Group 4	4				4	1		3	Raw Mix is fine, but process needs support
Dissemination of Best Available Technologies total	**16**				**16**	**9**	**4**	**3**	





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