Towards resource efficiency and decarbonising building materials in Argentina

Concrete and cement industry sector

Implemented by:

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

INTERNATIONAL CLIMATE INITIATIVE

based on a decision of the German Bundestag

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The project is funded through the International Climate Protection Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV).
The project IREK II focuses on cooperation with selected emerging G20 countries that present resource efficiency challenges and opportunities. It aims to contribute to the development and implementation of integrated concepts to improve resource efficiency and climate protection, with a focus on strengthening the competencies of key players in the public and private sector.

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Reviews

Dr. Dhiraj Rama

Industry Development Executive, Cement and Concrete SA, South Africa

"This publication provides an excellent review of the current state related to building materials use in Argentina. The pathways to achieve an ambitious and desired state by embracing a range of policy and strategic implementable interventions to attain appropriate resource efficiency are well founded and carefully informed. Furthermore, by engaging all the different stakeholders along the value chain provides for confidence and high degree of success to achieve both resource efficiency and decarbonising of building materials."

Damián M. Altgelt

Executive Director, Institute of Portland Cement, Argentine

"Climate Action and Sustainable Development impose important challenges on the sector's work agenda. Minimizing the carbon footprint is not only a possible technical action, but also necessary, unavoidable, and part of the involvement to achieve a more efficient, sustainable, and carbon-neutral construction industry in the long term. Innovation and multi-sector collaboration are central aspects to rethink the way we do things, and find new ideas that lead us to the desired goal. In this line, this work provides a useful look with a technical plan of possibilities for its application in our country, which invites to be analyzed and discussed by the different parties involved. We congratulate the authors and editors for this initiative, trusting that their contribution will be significant."

Dr. Mauricio Giraldo Orozco

Director Alternative Fuels, Cementos Argos S.A., Columbia

"The work developed in this study is not only a comprehensible path to aid in the decarbonization of the building sector of Argentina via the use of recycled aggregates, but one which is achievable in the short term under the conditions particular to the country, which can be used as an stepping stone for similar efforts in other Latin American nations and developing countries worldwide. Furthermore, the methodology applied to achieve this goal is a blueprint for other studies of similar reach due to the al around nature of the consultations done."

Edelio Bermejo

Head of Global R&D and IP, Holcim Innovation Center, France

"That's a very comprehensive and complete documents. It's scientifically solid. It's very adequately recommending the right measures that all stakeholders should undertake to drastically reduce the carbon footprint of concrete."

Matthias Mersmann

Chief Technology Officer, KHD Humboldt Wedag International AG, Germany

"Concrete is the most produced product on earth and can only be substituted to a very limited extent. The proportion of cement in concrete can only be substituted globally to a very limited extent, as can the proportion of clinker in cement. All in all, there will be no future without concrete and cement, while the world population will grow to over 10 billion people in the next few decades. This gives rise to the imperative task of driving forward the decarbonization of the building materials industry along the entire value chain as quickly as possible. To this end, the innovative power of all those involved must be increased to an unprecedented level in the greatest possible cooperation."

Foreword

Izabella Teixeira

Co-Chair of the International Resource Panel, UNEP

"The publication comes at the right time, when COP27 and COP15 made it clear that the world needs to close the gap between climate and biodiversity commitments and actions needed. Systemic integration of resource efficiency and material efficiency solutions in countries NDC submissions, as well as in national biodiversity plans is a way forward. This study is practical instrument that provides concrete measures focusing on cement and concrete industry which will help to achieve decarbonization of the building sector. The publication aims at helping to integrate resource efficiency and circular economies into national instruments and can serve as an example for successful decarbonization of building sector in other developing countries."

Contents

List of Tables

List of Figures

Acronyms

AAHE: Ready Mixed Concrete Association of Argentina (Asociación Argentina del Hormigón Elaborado)

AATH: Argentinian Concrete Technology Society (Asociación Argentina de Tecnología del Hormigón)

AFCP: Association of Portland Cement Manufacturers (Asociación de Fabricantes de Cemento Portland)

ECLAC: Economic Commission for Latin America

CIRSOC: Research Centre of National Safety Regulations for Civil Works (Centro de Investigación de los Reglamentos Nacionales de Seguridad para las Obras Civiles)

DNV: National Directorate of Roads of Argentina (Dirección Nacional de Vialidad)

FICEM: Inter-American Cement Federation (Federación Interamericana del Cemento)

GCCA: Global Cement and Concrete Association (Asociación Mundial de Productores de Cemento y Hormigón)

GHG: Greenhouse gases

GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. As a federal enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

ICPA: Argentinian Portland Cement Institute (Instituto del Cemento Portland Argentino)

INDEC: National Institute of Statistics and Censuses (Instituto Nacional de Estadísticas y Censos)

INTI: National Industrial Technology Institute (Instituto Nacional de Tecnología Industrial)

IRAM: Argentinian Institute for Standardisation and Certification (Instituto Argentino de Normalización y Certificación)

LEMIT: Multidisciplinary Training Laboratory for Technological Research (Laboratorio de Entrenamiento Multidisciplinario para la Investigación Tecnológica), Scientific Research Committee, Buenos Aires

WBCSD: World Business Council for Sustainable Development

Abbreviations and units

Mt: megatonne

m^3: cubic metre

CO_2eq: carbon dioxide equivalent

Glossary

Mineral admixtures: finely ground natural or industrial mineral materials, which may be added when manufacturing cement and concrete. Some admixtures do not require grinding, as the fineness obtained from primary processes is suitable (e.g. fly ash, silica fume).

Recycled aggregate: aggregate produced from waste building materials, particularly from concrete recovered from construction sites or from off-site processing plants (hardened concrete or materials obtained from washing fresh concrete waste).

Recycled coarse aggregate: coarse fraction recovered from construction demolitions, precast concrete items and hardened concrete waste (or materials obtained from washing fresh concrete waste) crushed in an off-site processing plant.

Mixed coarse aggregate: coarse fraction comprised of a mixture of aggregates (natural or broken aggregate, broken rocks and recycled aggregates).

Minor constituents: natural minerals or minerals derived from the clinker manufacturing process or mineral additions (granulated blast furnace slag, calcareous filler, natural or industrial pozzolans, siliceous fly ash) that may be added when manufacturing cement.

Recycled concrete: mixture prepared with materials recovered from demolished concrete or from waste recovered from off-site processing plants (fresh or hardened concrete, or unused precast concrete items).

Foreword

Promoting resource efficiency in the cement and concrete industry is a priority to meet the social and environmental challenge of increasing competitiveness, innovation and employment, while contributing to the reduction of GHG emissions.

The accelerated use of global resources over the last 50 years has intensified problems such as climate change, land degradation and biodiversity loss. In 2015, material production was responsible for 23% of global greenhouse gas (GHG) emissions, and this proportion continues to grow. The construction sector is one of the main consumers of materials and GHG generators within industrial processes as a whole.

For this reason, promoting resource efficiency in the cement and concrete industry is a priority to meet the social and environmental challenge of increasing competitiveness, innovation and employment, while contributing to the reduction of GHG emissions. At the same time, the public, private, and scientific-technological sectors must be coordinated so that policies and instruments can be developed to improve specific practices and technologies in the construction sector.

In line with the global climate action targets agreed in the Paris Agreement, Argentina is committed to the United Nations 2030 Agenda. In this context, the project Initiative for Resource Efficiency and Climate Action, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, supports Argentina in developing proposals for measures and instruments for the country's strategic production sectors which have the potential to reduce GHG emissions. The project actions are funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUV) as part of the International Climate Initiative (IKI).

This paper is the result of the professional work and consultation process with key public, private and academic stakeholders. A sectoral analysis is presented, the main problems are identified, and measures are proposed to reduce GHG emissions.

"Towards resource efficiency and decarbonising building materials in Argentina" aims to contribute to the policy discussion on the future development of the building materials industry; furthermore, a scenario is presented with specific action points which will undoubtedly be relevant for Argentina's national climate change strategy.

In addition to the challenge of implementing the proposed measures, the project has the objective of progressing the analysis of other production sectors with a view to decoupling economic growth, resource use, and GHG emissions.

1

Introduction

1

Introduction

This paper proposes strategies and actions to reduce GHG in the cement and concrete industry.

The Argentinian construction value chain has a variety of materials and products which are applied in construction processes for public and private works. The daily activities of the cement, mortar and concrete industry undoubtedly make a significant mark on the country's production scenarios beyond the scale of the actual construction works.

Moreover, these sectors are some of the main material consumers and GHG producers within industrial processes as a whole according to Argentina's GHG Inventory[1]. This is one of the reasons behind the search for alternatives to improve these aspects.

SCOPE AND LIMITATIONS

This paper introduces resource efficiency strategies to progressively reduce GHG emissions in the construction industry, particularly in the cement and concrete production areas.

Broadly speaking, GHG reduction strategies and actions for the cement and concrete industry can include several approaches such as energy efficiency, co-processing of materials such as alternative fuels, carbon capture, resource efficiency, lowering the clinker factor, etc.

It is important to clarify that the guidelines and strategies discussed are limited to resource efficiency without considering energy or water, and to setting out tools to help reuse industrial by-products and materials as inputs in the manufacturing processes and during construction.

1. https://inventariogei.ambiente.gob.ar

2

Objectives

OVERALL OBJECTIVE

1. Describe
2. Identify and validate
3. Propose

The overall objective of this paper is to “contribute to the ongoing policy discussion on future development towards a decarbonised building materials industry in Argentina through resource efficiency strategies and a focus on material efficiency in the cement and concrete industry”.

SPECIFIC OBJECTIVES

- To describe the current state of the cement and concrete sector in Argentina.
- To identify and validate key stakeholders and feasible measures that contribute to reducing emissions and increasing resource efficiency in the sector.
- To propose inputs for a roadmap to help improve resource efficiency and reduce GHG emissions in the cement and concrete industry in Argentina.

This paper is aimed at the Ministry of the Environment and Sustainable Development and the Ministry of Productive Development of Argentina; the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection; business associations; and technical and technological institutions and organisations.

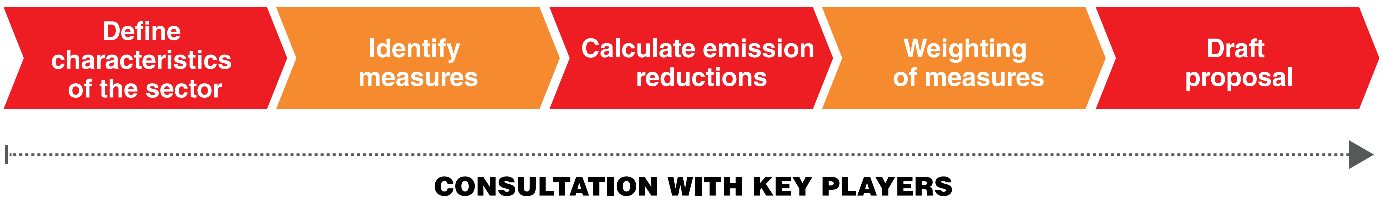
3

Research methodology

Stakeholder engagement and the drive towards material quality in the construction value chain were established as key premises for this initiative. The use and addition of by-products during production and improvements to the life cycle of materials were also considered.

We carefully planned the work and structured it into five aspects (see **figure 1**). We defined the characteristics of the sector first, after which we identified resource efficiency measures which were used to calculate emission reductions. The measures were weighted based on this information. Finally, we consolidated the resource efficiency and emission reduction proposal for the cement and concrete industry.

Figure 1
Research methodology.



This process took place between July and November 2021. We carried out a number of activities during this period, including:

- Gathering available documents, studies, latest developments, research and innovations on cement and concrete manufacturing. We identified applicable technical standards and regulations on the matter. The aim was to characterise the state of the art and to identify potential opportunities and constraints of resource use in the sector.

- We produced a map of stakeholders that could provide input and/or be key players (positive/negative) in the proposal process (including identifying, developing and later implementing resource efficiency and emission reduction measures in the sector).

- We developed the structure of the initiative, separated into the corresponding blocks (see **figure 2**). We put forward an initial proposal of the 2030 strategic vision for the sector. This involved incorporating resource efficiency and emission criteria to be validated with public and private key players.

- We held a kick-off meeting with representatives from the National Climate Change Directorate (Climate Change, Sustainable Development and Innovation Cabinet under the Ministry of the Environment and Sustainable Development, Argentina). We presented the objective of the work, its proposed structure, and the previously developed strategic vision for the cement and concrete sector in this meeting.

- First consultation and enquiry round with recognised experts and representatives of various pre-selected stakeholders: Association of Portland Cement Manufacturers (AFCP); Argentinian Portland Cement Institute (ICPA); Ready Mixed Concrete Association of Argentina (AAHE); Argentinian Association of Concrete Technology (AATH). The aim was to exchange ideas on alternatives to improve resource efficiency and reduce emissions in the sector. We highlighted the potential qualitative and quantitative impact of these alternatives.

- We identified potential resource efficiency measures that could contribute to reducing emissions in both the cement and concrete industries.

- We identified barriers and opportunities to each of the potential measures. We carried out an initial gap analysis, determining the needs and/or deficits of the cement and concrete industries. We also carried out a feasibility analysis on the implementation of each individual measure.

- We prioritised six measures according to their feasibility and potential impact.

- We estimated the time and investment required to implement each of the six prioritised measures.

- We calculated the emission reductions for each of the measures, proposing possible scenarios for implementing them by 2030 based on cement and concrete production volumes. The year 2019 is taken as the baseline based on CO_2eq emission information from AFCP and AAHE (Argentina). We calculated the direct emissions corresponding to the production of each material. We then weighted the measures in terms of impact, cost and implementation time.

- We developed a preliminary Resource Efficiency and Emission Reduction Plan for Argentina's cement and concrete industry by 2030.

- Second consultation round and validation with key players. The preliminary Plan was discussed and contributions from each participant were considered.

  » We presented the initiative to the Climate Change, Sustainable Development and Innovation Secretary (Ministry of the Environment and Sustainable Development), where the authorities, and climate change and sustainable construction experts took part.
  » New working groups were set up, expanding participation to leading experts in the technical, professional, regulatory, and technological development sectors. This included representatives of ICPA, AAHE, AATH, AFCP, LEMIT, INTI, CIRSOC, and the cement companies Loma Negra, Holcim Argentina (Argentine) and Cementos Avellaneda.

- We analysed specific documentation to validate the data considered in this paper.

- We developed a final version of the Resource Efficiency and Emission Reduction Plan for Argentina's cement and concrete industry by 2030.

- The documentation was reviewed by national experts with international profiles. This included experts from academia, production, civil, technical, and professional associations, and representatives of the technical climate change area in the public sector.

The final version of the Resource Efficiency and Emission Reduction Plan for Argentina's cement and concrete industry by 2030 was therefore consolidated following an interactive and participatory process that engaged national key players.

STRUCTURE OF THE INITIATIVE

Figure 2
Structure of the Initiative.

1. Definition of the strategic framework

This point involves briefly describing the background of the construction industry in Argentina. The cement industry and ready mixed concrete manufacturing are discussed. Covers the current situation and most relevant data.

2. Stakeholders

The stakeholders surveyed and key players involved are described. Challenges and opportunities arising from the analysis are explored.

3. Development of Strategic Plan

Plan vision and objectives. Critical aspects and barriers to overcome. Potential instruments are presented and prioritised. Activities or steps that form the roadmap.

4. Best practice

Strategies related to disseminating the insertion of sustainable materials and technologies in construction.

2

Sector Plan

1

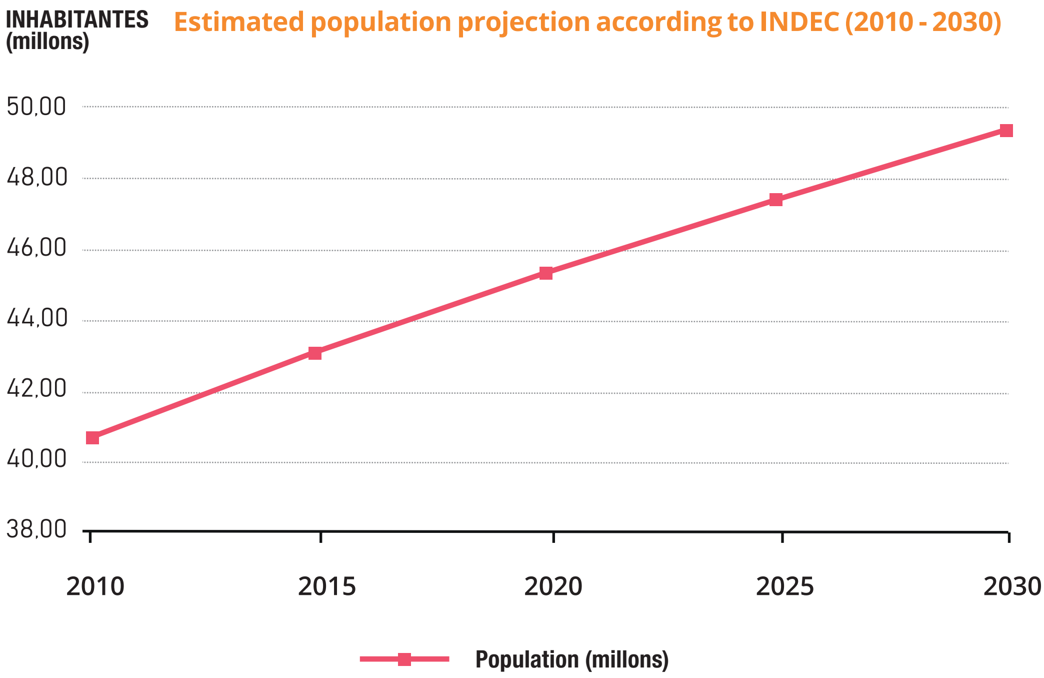
Sector Context

BACKGROUND OF THE CONSTRUCTION INDUSTRY

Argentina is characterised by its vast territory, with a total surface area of 3 761 274 km² (INDEC, 2019). According to the 2010 National Census the country had a population of 40 117 096 inhabitants, resulting in a population density of 10.7 inhabitants/km² (INDEC, 2010).

National population projections (refer to **figure 3**) based on the 2010 National Population and Housing Census estimate that the country would currently have a population of 45 808 747 inhabitants, which is expected to reach 49 407 265 in 2030 (INDEC, 2021), meaning the population density would increase to 13.1 inhabitants/km².

Figure 3
Estimated population projection.



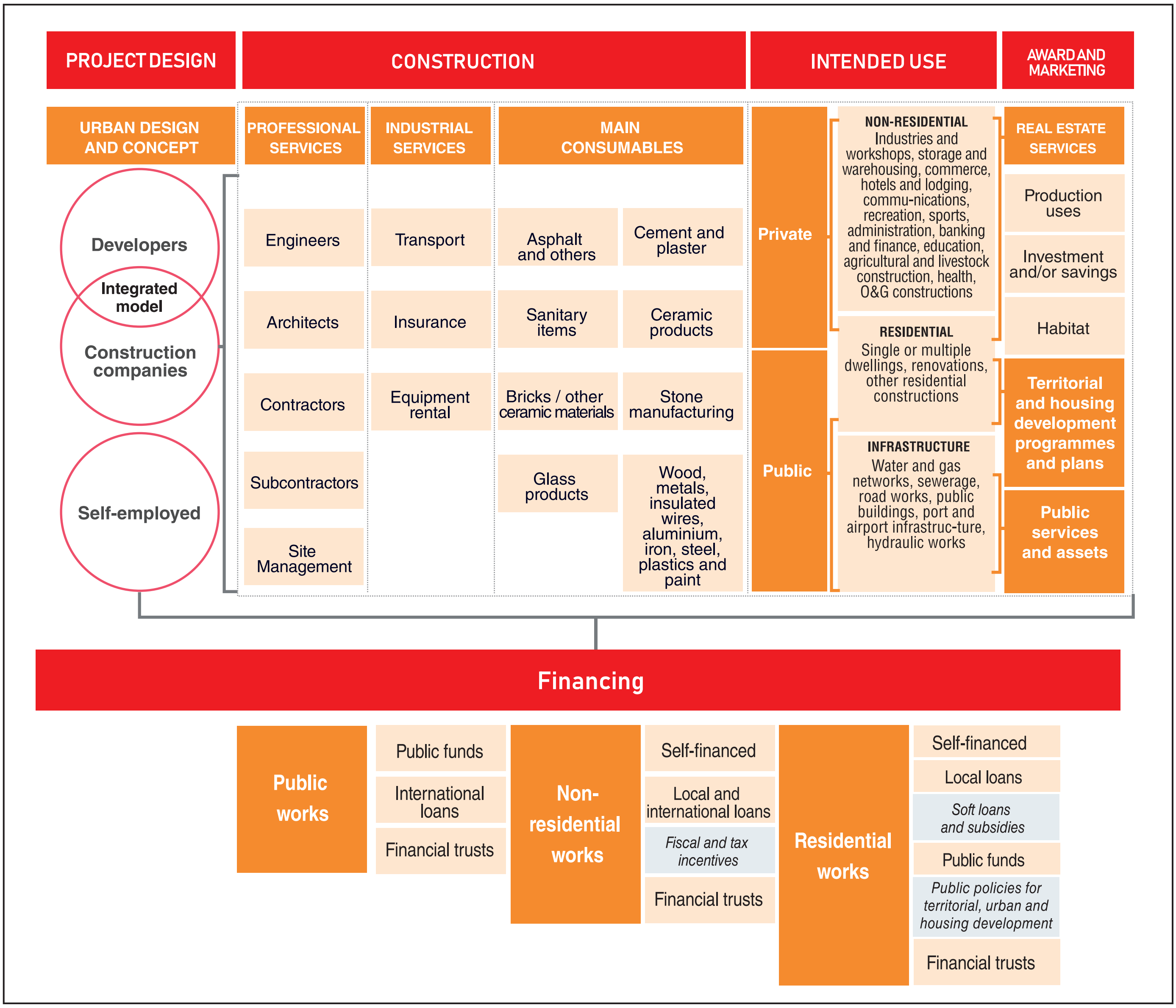
Source: *National estimations and projections. Table 1. Estimated population at 1 July each year. Entire country (INDEC, 2021).*

The construction industry has historically been linked to progress.

The construction industry has historically been linked to progress, having to adapt to the technological, economic and social contexts of each geographical region. Organisations have had to readjust to these situations by incorporating new technologies and methodologies aimed at improving their competitiveness.

The publication "Report on the Value Chain. Construction Sector" (Ministry of Economy, 2020) exposes the importance of the sector and its impact on the economy in terms of investment, job creation, and its connection with other production areas. The sector accounts for 3.6% of the country's Gross Value Added (GVA, 2019).

Figure 4
Diagram of the sector's value chain.



Source: *Report on the Value Chain. Construction Sector (Ministry of Economy, 2020).*

Employment in construction accounts for 6% of total registered employment in the country. However, informal employment is estimated to account for approximately 75% in 2019. Given the nature of the sector, different degrees of skills and specialisation are required to suitably produce and apply building materials.

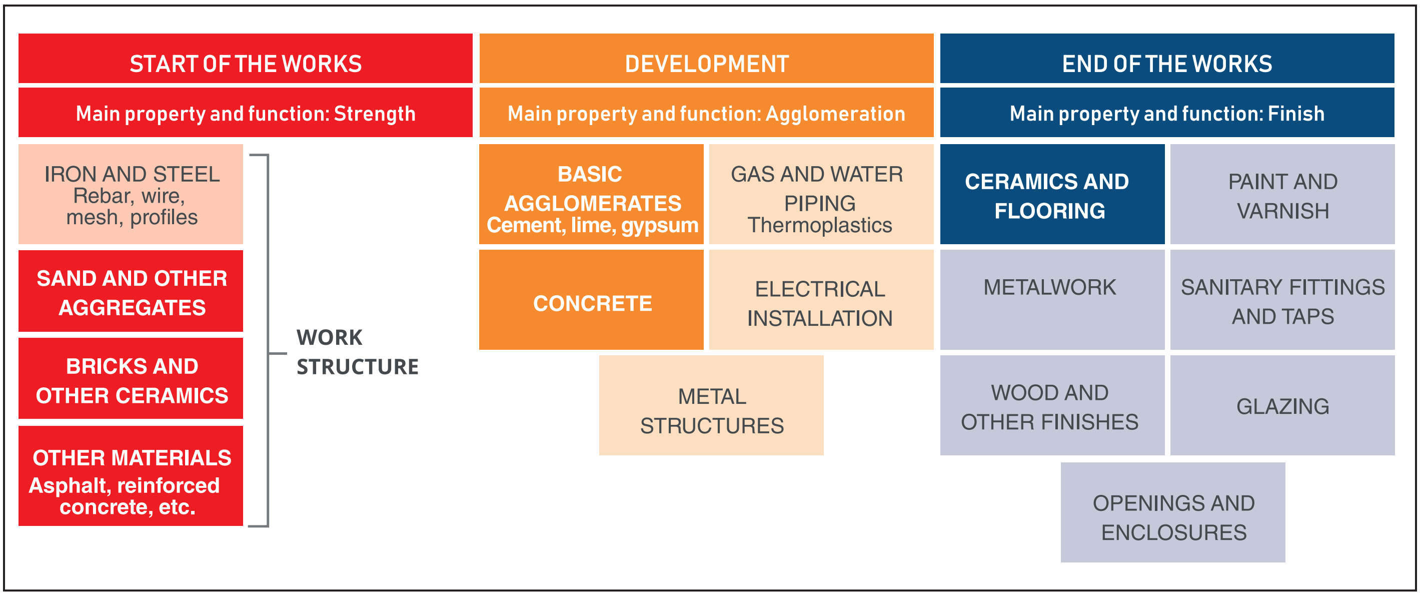
Production and service activities are involved during the project development stage, during construction for main and complementary works, as part of procurement during construction, and they also form part of conformity assessments and construction marketing (refer to **figure 4**).

Projects involve public and private works in urban, suburban, and rural areas. They are used for housing, industry, commerce, education, health, transport, energy, sports, entertainment, tourism, and public infrastructure (communications, transport, water, and services, among others).

The most commonly used range of products and inputs for such works involve mortars and concrete (refer to **figure 5**). This covers structural and non-structural mortars and concrete as well as derived products such as ready mixed mortar for plastering and masonry work and adhesives for cladding.

Cement-based binders include structural cements (for general use with special properties and cement used to produce concrete roadways made with high-performance technologies), masonry cements, limes, and plasters.

Figure 5
Consumables in the construction process.



Source: *Report on the Value Chain. Construction Sector (Ministry of Economy, 2020).*

DEVELOPMENT OF THE CEMENT AND CONCRETE INDUSTRY

The National Portland Cement Factory was set up in Cordoba, Argentina, in 1907.

The cement industry in Argentina dates back to the middle of the 19th century, with the influence of the European school. Following several attempts, the National Portland Cement Factory was eventually set up in Cordoba in 1907. Since then, the cement industry has continued to evolve technologically to meet the quality requirements of new civil and infrastructure works.

What was known as pure cement (clinker + gypsum) was initially manufactured. Mineral additions were later incorporated. These included finely ground active or quasi-active mineral additions and pozzolans. Blast furnace slag obtained as a waste by-product of the steel industry was later introduced. Finely ground mineral additions are mostly used to replace part of the clinker in the cement production process. Specific studies are required to define the most suitable range of proportions that can be used. Concerns about sustainability issues have generated greater interest in the use of this type of raw material in manufacturing.

Calcareous filler as an inert addition was added to the range of mineral additions towards the end of the 20th century. Calcareous filler is an inorganic material obtained from a natural mineral (limestone rock). It mainly consists of finely ground calcium carbonate.

The development of cements with mineral additions, the study of their properties, issues related to sustainability, production and transportation costs, use of non-renewable resources as well as control of conformity and suitability led to changes in the conception and classification of local cements.As a result, the standards were changed in early 2000: IRAM 50000, cement for general use (2000); IRAM 50001, cement for special use (2000). The standards IRAM 50002 cement for road use (2009) and IRAM 50003 conformity assessment (2017) were later added. Some of these standards have been updated at different times.

Studies are currently being developed around the world that have succeeded in activating special clays by calcination. This provides new possibilities for clays with suitable pozzolanic properties to be used as artificial mineral additions. In Argentina, innovation processes are entering the manufacturing industry to create cement with mineral additions combining calcareous filler and activated clays to replace natural puzzolans (Irassar, E. et al, 2019)..

Almost parallel to the development of the cement industry, the ready-mix concrete industry developed. Numerous plants distributed throughout the country with different degrees of technological development and performance were installed.

Construction during the 1940s and 1950s was marked by European influences and the use of technologies, particularly of German origin. The Draft Regulation for Concrete Structures in Argentina (PRAEH) was developed around 1960. It was applied for a number of years but was never actually approved as a Regulation (INTI-CIRSOC, 2006).

The industry has evolved from offering traditional concrete to creating new concrete with special high-performance properties.

The Research Centre of National Safety Regulations for Civil Works - CIRSOC 201-82 Regulation was produced in 1982. While this Regulation was only mandatory for public works of a national scale, many provinces adopted it for provincial, municipal and private works.

The use of chemical additives as part of the mix design also began to expand during this time. The aim was to improve the performance of fresh and hardened concrete. The fluidity, strength, and durability of concrete were becoming critical factors in the technological developments. The possibility to reduce costs also gave the product a remarkable competitive advantage in the market.

In 1996, the study of a second generation of Regulations was commissioned, based on the US standards used in other countries of the region. CIRSOC Regulation 201 M: 1996 (Design, calculation and construction of prestressed reinforced concrete structures for municipal private works) was prepared. Later, in 2005, CIRSOC 201:2005 (Argentine Regulation of Concrete Structures) was drawn up and came into force in 2013.The landscape of Portland cement manufacturers changed towards the year 2000. It consisted of four dominating business groups which are still active today: Grupo Loma Negra C.I.A.S.A., Minetti (currently known as Holcim Argentina), Cementos Avellaneda S.A. and Petroquímica Comodoro Rivadavia S.A.

The landscape of Portland cement manufacturers changed towards the year 2000. It consisted of four dominating business groups which are still active today: Grupo Loma Negra C.I.A.S.A., Minetti (currently known as Holcim Argentina), Cementos Avellaneda S.A. and Petroquímica Comodoro Rivadavia S.A.

These groups changed the ready mixed concrete market by adding production units to their businesses, acquiring plants in different areas of the country. These companies currently market one or more of the following products: limes, hydraulic binders, adhesives, pastes, stone aggregates, and precast concrete.

The industry has evolved from offering traditional concrete to creating new concrete with special high-performance properties. The first self-compacting concretes and concretes with qualities called H-45 and H-60 were created and implemented on construction sites.

Today, a variety of concrete products can be found on construction sites which respond to the strength and durability requirements of new structural designs. Very-high performance concretes (H-80 and H-110) have been achieved in some Metropolitan cases, some of which have special characteristics such as self-compacting characteristics.

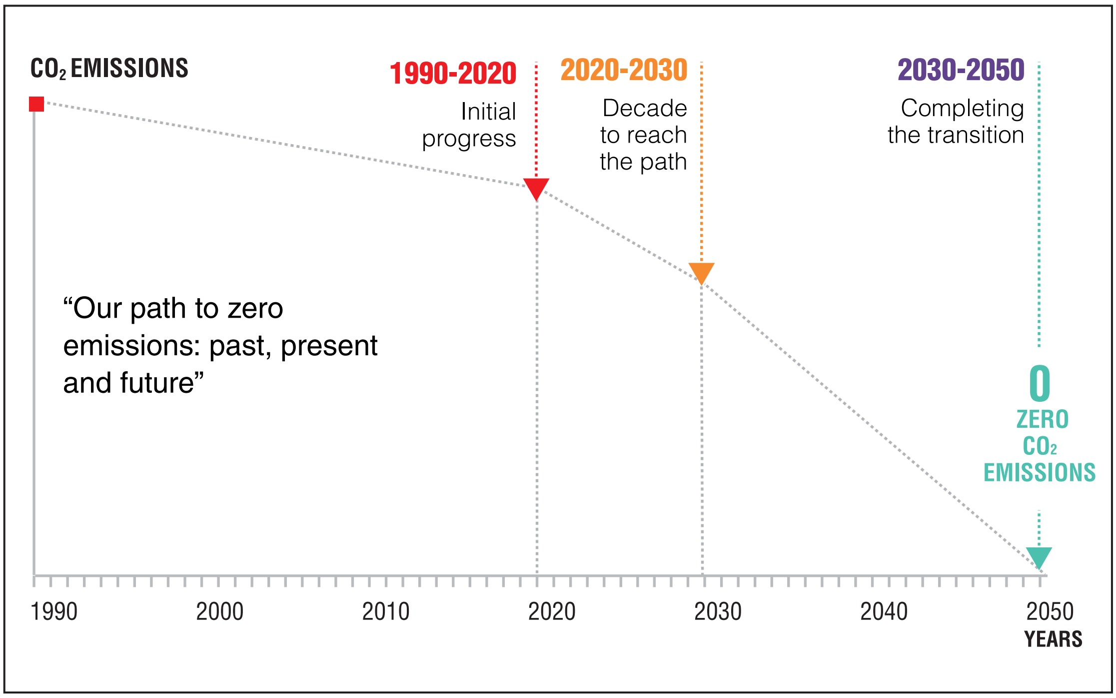
SUSTAINABILITY IN THE CEMENT AND CONCRETE INDUSTRY

The characteristics of concrete including its high strength and durability, its ability to be fully or partially reused, and the little to no maintenance it requires make it one of the most widely-used materials in construction. The Global Cement and Concrete Association (GCCA) estimates that approximately 14 billion m^3 of concrete are produced worldwide every year (GCCA, 2020).

Concrete can be fully or partially reused.

The GCCA published a summary document of the Roadmap for Carbon Neutral Concrete by 2050. This roadmap reflects the cement and concrete industry's ambition, vision, and collective commitment to full decarbonisation within this time period by gradually reducing CO_2 emissions. A reduction of 25% per m^3 of concrete and 20% per tonne of cement by 2030 have been proposed, taking 2020 as the baseline (refer to **figure 6**).

Figure 6
Reduction in CO_2 emissions proposed by the GCCA.



Source: Future of concrete. Plan 2050 Graph. (GCCA, 2020).

The main source of GHG emissions in Argentina within the "Industrial process and product use" sector comes from the minerals industry, which represented 35% of emissions in 2016 (refer to **figure 7**) reaching 7 Mt of CO_2eq per year: 4.13 Mt CO_2eq come from cement production and 2.16 Mt CO_2eq from lime production[2].

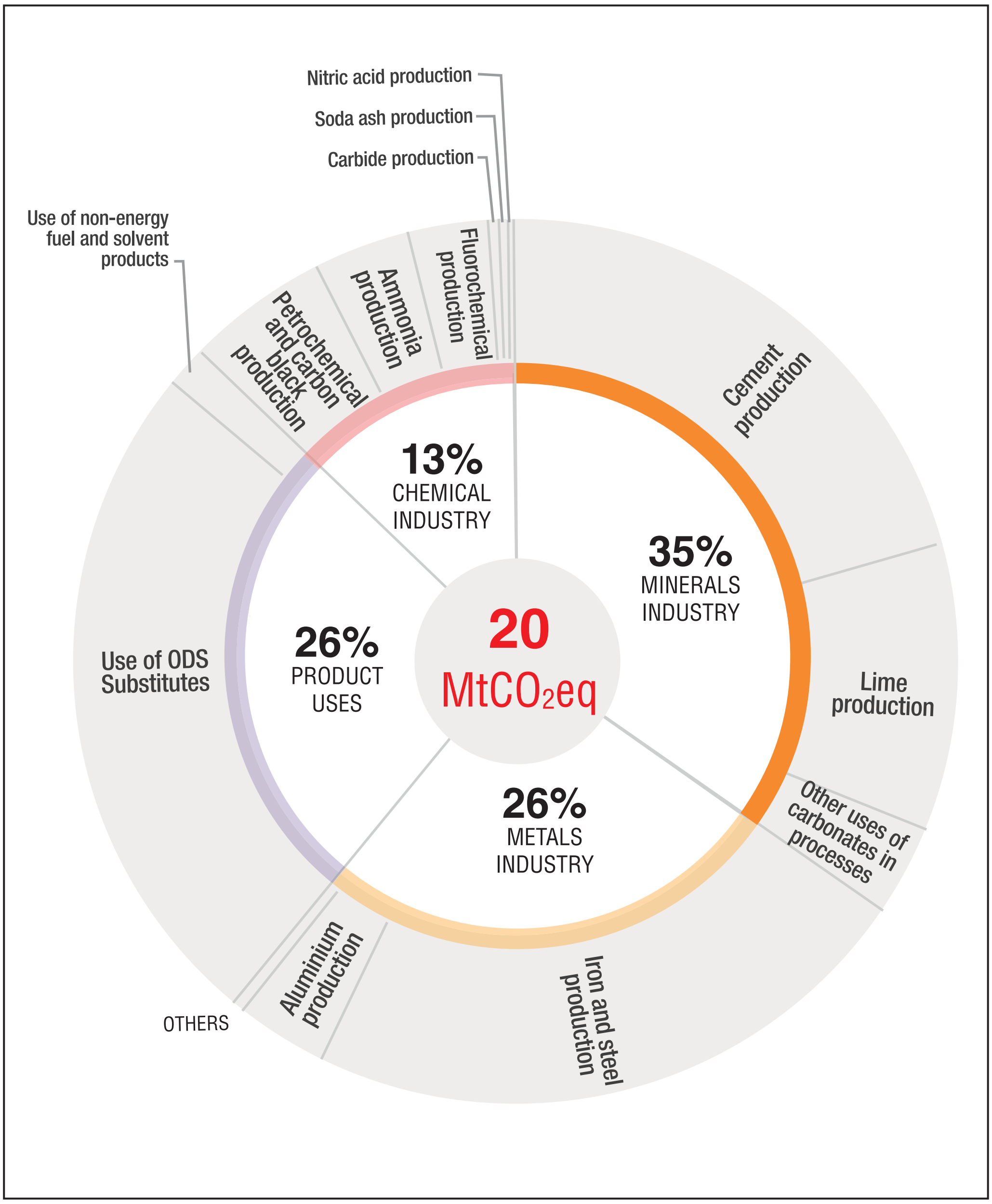


Figure 7
Industrial processes and product use, GHG Inventory 2016.

Source: *Argentina's National GHG Inventory. Industrial processes and product use sector. 2016 Data.* *https://inventariogei.ambiente.gob.ar/files/inventario-nacional-gei-argentina.pdf*

2. According to the Ministry of the Environment and Sustainable Development. https://inventariogei.ambiente.gob.ar/re-sultados. 15-11-2021

The sustainability perspective has promoted the study of more environmentally friendly materials.

The manufacturing process of clinker, an intermediate product in cement production, directly and indirectly generates gaseous CO_2 which is emitted into the atmosphere. It mainly comes from the combustion and grinding of limestone as part of the decarbonation process, among other operations.

The sustainability perspective has led to a growing interest in studying more environmentally friendly materials (cement products, mortars, concrete and alternative by-products).

In October 2021, the Association of Portland Cement Manufacturers (AFCP) organised a series of four meetings with specialists aimed at disseminating specific knowledge on the Circular Economy, Innovation, and Climate Action. These meetings were sponsored and supported by other entities in the sector:

Science and technology institutions have a growing interest in the research, development, and technological innovation of sustainable materials.

- Argentinian Portland Cement Institute (ICPA)
- Concrete Block Association (AABH)
- Argentinian Road Association (AAC)
- Ready Mixed Concrete Association of Argentina (AAHE)
- Structural Concrete Association of Argentina (AAHES)
- Argentinian Association of Concrete Technology (AATH)
- American Concrete Institute (ACI) - Argentina Chapter
- Association of Structural Engineers (AIE)
- Argentinian Association of Engineering Consulting Firms (CADECI)
- Argentinian Centre of Engineers (CAI)
- Argentinian Chamber of Construction (CAMARCO)
- Argentinian Business Council for Sustainable Development (CEADS)
- Portland Cement Precast Industry Association (CIPCP)
- Central Society of Architects (SCA)
- Argentinian Industrial Union (UIA)

Several research centres and groups across the country have developed lines of research into the use of recycled aggregates and concrete as well as studies on mineral additions or supplementary materials to produce cement.

- The Multidisciplinary Training Laboratory for Technological Research (LEMIT) under the Scientific Research Committee (CIC) in the Buenos Aires Province has records of scientific research into recycled aggregate for concrete since the late 1990s. This research started with studies into the different properties of recycled coarse aggregates as detailed in the paper "Recycled concretes: research carried out at LEMIT during the last 18 years" (Di Maio, A. 2018). This is one of the lines of work that LEMIT initiated in 2001 and which continues to date. This was confirmed by one of the experts consulted as part of the process, Dr. Claudio Zega, whose doctoral thesis explores the physical-chemical and durability properties of recycled concrete.

In the VI International Congress and 20th Technical Meeting "Ing. Alberto S.C. Fava" several articles were presented that deal with the subject of sustainable concrete, recycled coarse and fine aggregates and their behavior in mortar and concrete mixtures from the mechanical and durability point of view (Sosa, M, Zega, C and Di Maio, A , 2014).Work was also presented on reusing industrial by-products and ceramic demolition waste in concrete (Zito, S. and Rahhal, V., 2014).

Work was also presented on reusing industrial by-products and ceramic demolition waste in concrete (Zito, S. and Rahhal, V., 2014).

Other studies based on the sustainability of building materials focus on optimising mixtures to manufacture building blocks and paving blocks (Agnello, J., Benitez, A. and Fernández Luco, L., 2014).

- The National Industrial Technology Institute (INTI) organised its First Conference on the Reduction, Reuse, Recycling and Recovery (the so-called 4Rs) of industrial waste in 2015. A book titled "The value of waste: different ways to reduce, reuse, recycle, and recover industrial waste" was published in 2016 following the conference. The book summarises studies by specialists on precast and paving elements using recycled aggregates and reusing cellulose in cement mixtures, among other aspects (INTI, 2016).

Examples of R&D+i projects in universities include the following:

- At the UTN's Regional Avellaneda Faculty, the Quality Group for Production and Services (Ca.Pro.Ser.) has been carrying out research activities in civil engineering on sustainable construction since 2004. It involves the development of new materials and concretes that reuse waste by-products from industry (reuse of polymers, recycled materials, precast design, etc.) (García, A. et al, 2014), (García A., Mazzeo J., Ruiz, L. and Martínez, G., 2014).

Since 2015, the group has focussed on applying recycled concretes for road works using aggregates generated by demolitions and by-products. (García, A. et al, 2020), (García A., Martínez G. and Mazzeo J., 2017).

- Another case is the Centre for Research, Development and Transfer of Materials and Quality (CINTEMAC). Research has been carried out on the use of recycled construction waste from different sources with varying physical-mechanical and durability properties (2004-2006) and (2007-2010) (Andrada, C., Baronetto, C. and Positieri, M., 2008).

- Research activities are also carried out at the National University of the South which is presented at scientific events. This includes studies into the behaviour of materials in aggressive environments, assessing pathologies such as corrosion in recycled concrete structures (Meneses, R., Moro, J. and Ortega, N., 2014).

- Developments are being made on sustainability at the National University of Central Buenos Aires. The poster "Blended cement with illitic calcined clay and calcareous material" by F. Irassar, V. Bonavetti and Castellano, C. was awarded a prize from among 127 submissions at the 15th International Congress of Cement Chemistry in the Czech Republic on Supplementary Cementitious Materials (ICCC, 2019). A scientific paper on the matter has recently been published in the Hormigón (Concrete) Journal ISNN-e 2718-9058 (Bonavetti et al, 2021).

2

Current sector situation

BASIC SECTOR DATA

The cement industry is represented in Argentina by Loma Negra S.A., Holcim Argentina, Cementos Avellaneda and members of the AFCP.

The cement industry is currently distributed over the entire country. It is represented by four cement manufacturers, Loma Negra S.A., Holcim (Argentina) S.A., Cementos Avellaneda S.A. and Petroquímica Comodoro Rivadavia S.A. (PCR), all of which are members of the AFCP.

Annual production reached 11 923 660 t in 2019[3], of which 11 081 728 t was used for structural cement and 841 932 t for masonry cement (AFCP, 2020).

Cement is delivered in 50 kg bags or in bulk using mobile silos transported by road or rail, or in bulk bag format. Cement is generally delivered in bulk to concrete manufacturing companies, to manufacturers of precast parts or industrialised by-products, and to construction companies. Other commercial suppliers, construction sites, and users purchase cement in bags. Masonry cement is delivered in 40 kg bags (AFCP, 2020).

Industrial production of Portland cement (AFCP).

CEMENT PRODUCERS (AFCP)		
CEMENT FOR STRUCTURAL USE: 11 082 THOUSAND TONNES PER YEAR	MASONRY CEMENT: 842 THOUSAND TONNES PER YEAR	TOTAL 11 924 THOUSAND TONNES (2019)

3. Production values for 2019 have been used as a reference given the impact of the COVID-19 pandemic on global economies

The cement industry covers the production of general-purpose cements, cements with special properties, masonry cement, and cement used to produce concrete for roadways made with high-performance pavers.

The Ready Mixed Concrete Association of Argentina (AAHE) brings together 200-250 companies in the sector. Of these, 36 were certified according to the requirements of the IRAM ISO 9001 standard. According to the AAHE's annual report, associated companies generated 5 436 186 m^3 of ready mixed concrete.

Concrete production (AAHE associates).

Ready Mixed Concrete Association of Argentina AAHE

- 200 to 250 associated companies in the sector

5.44

million m^3 TOTAL ready mixed concrete (AAHE, 2019)

36

companies certified according to IRAM ISO 9001

According to information provided by several key players during interviews, it is estimated that the volume of concrete corresponding to AAHE members represents 50% of the total annual production volume. The remaining 50% corresponds to mortars and concrete produced by companies not associated with the AAHE, including concrete mixing companies, construction companies, producers of precast and prestressed elements, and cement-based mortar producers. This does not include mortar and concrete dosed and produced on site.

Production by other companies in the sector (non-AAHE members).

Other companies in the sector

- Concrete producers (non-AAHE members)
- Construction companies
- Precast and prestressed elements
- Other concrete and mortar products and construction elements

5.50

Million m^3 of ready mixed concrete in total (AAHE, 2019)

While there are companies that manufacture concrete products and parts for construction projects, mortar and concrete is usually produced on site. Exhaustive controls of the final material quality and production processes must be implemented in all cases. In the case of industrial products, quality parameters can be better controlled at the manufacturing plant. In the case of concrete, controls are carried out when materials are received on site, as well as where the concrete is manufactured.

MATERIAL-RELATED PROBLEMS IN THE CEMENT AND CONCRETE INDUSTRY

A brief analysis of the current situation in the sector related to material uses is presented below. This analysis is used as the starting point for the Resource Efficiency Plan and the Decarbonisation of Building Materials later in this paper.

AGGREGATES IN CONCRETE

The granular structure of concrete mixtures is mostly composed of aggregates, which could account for around 70-90% of the concrete mass depending on the concrete type, quality, and performance. Natural aggregates are used in most cases, although other by-products such as slag have also been used.

Options are being explored to use by-products from concrete mixtures, construction waste, and concrete and construction demolition products as aggregates. Several studies have been published internationally and in Argentina on reusing recycled materials as coarse and fine aggregates.

The Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development published "The Cement Sustainability Initiative. Recycling Concrete" (WBCSD, 2009), which detailed proportions of coarse and fine recycled aggregate used in different areas of the world. Examples of recycled aggregate use at the time the report was published were Japan (80%), USA (82%), and Europe (30%). These percentages have now been exceeded.

An analysis of the percentage of recycled construction and demolition waste (CDW) that can be used as aggregate according to specifications and standards in different countries for different types and applications of concrete is presented in figure 8 (Alberte, E. and Handro, J., 2021).

Figure 8. Application conditions of recycled aggregates in concrete according to specifications.

Country	Norma	Classification		Application	Synthesis (%)		Conditions of use	Maximum strength (or class) of the concrete produced
		Standard	Unified		Coarse aggregate	Fine aggregate		
Brazil	NBR 15116 (ABNT, 2004)	ARC	ARC	Non-structural	≤100		-	C15
		ARM	ARM				-	
Germany	DIN 4226-100 (Deutsches, 2002)	Type 1	ARC	Structural	≤45	0	Exposure classes X0, XC1 to XC4, XF1-XF3, XA1. Not allowed to be used in prestressed concrete	35 MPa
		Type 2	ARC		≤35	0		
		Type 3	ARCE	Non-structural and mortars	-		Non-structural concrete and mortars	-
		Type 4	ARM		-			-
Australia	HB 155 (COMMONWEALT H, 2002)	Class 1A	ARC	Concrete	≤30	0	Structural concretes with lower doses, permeability, and shrinkage properties	40 MPa
		Class 1B	ARM		≤100	0		25 MPa
Belgium	NBN B15-001 (BELGIUM, 2006)	ARC	ARC	Structural	≤20	0	Exposure classes X0 and XC1	C30/C7
		ARM	ARM	Non-structural	≤100	0	-	C16/20
Spain	EHE-08 (MINISTERY, 2008)	ARC	ARC	Structural	≤20	0	Except in prestressed concrete	40 MPa
				Non-structural	≤100	0		
	Basque Government Public Company for Environmental Management (2011)	ARM	ARM	Non-structural	≤100		-	C15
	GEAR-RT-04 (GREMIO, 2012)	ARH	ARC	Precast concrete items	20 a 100	-	Favourable climate conditions and no exposure to freezing or thawing	-
		ARMh	ARC			-		-
		ARMc	ARM			-		-
	GEAR-RT-05 (GREMIO, 2012)	ARH	ARC	Concrete mixtures	-		-	Structural: 30 MPa; Non-structural 20 Mpa
		ARMh	ARC		-		-	
		ARMc	ARM		-		-	
USA	FDOT (FLORIDA, 2017)	ARC	ARC	Non-structural	-	-	-	-
	TxDOT (TEXAS, 2014)	ARC	ARC	Non-structural	-	-	-	-
	MDOT (MICHIGAN, 2012)	ARC	ARC	Non-structural	-	-	-	-
The Netherlands	NEN 5905 (ROYAL, 2005)	ARC	ARC	Concrete	≤100	-	Favourable climate conditions and non-aggressive environments	C40/C50
		ARM	ARM		-			20 MPa
Hong Kong	WBCT N°12 (DEVELOPMENT,2002)	ARC	ARC	Structural	≤20	0	-	35 MPa
				Non-structural	≤100	0	-	20 MPa
England	BS 8500-2 (BRITISH,2002)	ARC	ARC	Structural	≤100	0	Exposure classes X0, XC1, XC3, XC4, XF1, DC1	C40/C50
		AR	ARCE	Non-structural	≤20	0		C16/20
	BRE DIGEST 433(BUILDING,1998)	AR I	ARCE		-	0	-	C20
		AR II	ARC	Structural	-	0	-	C35
		AR III	ARM	Concrete	≤20	0	-	-
Japan	Building Contractors Society of Japan (1977)	AR	ARM	Non-structural	≤100		Foundation elements	18 MPa
	JIS A 5021 (2005)	ARH	ARC	Structural	-		-	45 MPa
	JIS A 5022 (JAPANESE, 2006)	ARM	ARC		-		Not exposed to frost or thawing	
	JIS A 5023 (JAPANESE, 2007)	ARL	ARC	Non-structural	≤100		-	-
Switzerland	OT 70085 (JAPANESE, 2006)	ARC	ARC	Concrete	≤100		-	-
		ARM	ARM				-	-
International	RILEM (1994)	AR Type 1	ARCE	Concrete	≤100	Not recommended	Dry and humid environments without aggressive chemical	C16/20

Source: *State-of-art review of current standards and specifications concerning recycled aggregates from CDW. (Alberte, E. and Handro, J., 2021).*

The book "Basis of a Model Code for the Technology of Concrete Works" (Giovambattista et al, 2019) includes a chapter on "Concretes with special characteristics". It states that the strength and durability characteristics of recycled concretes made with 30% recycled coarse and fine aggregates by volume are similar to conventional concrete according to various studies.

• CURRENT SITUATION - TECHNICAL STANDARDS FOR CONCRETE AGGREGATES

The IRAM standards regulate the use of coarse (IRAM 1531) and fine (1512) aggregates.

1. IRAM 1531:2016. COARSE AGGREGATE FOR CEMENT CONCRETE.

The latest version establishes the possibility of incorporating recycled and mixed aggregates to produce concrete. The term mixed aggregate implies the use of natural or crushed aggregates and recycled aggregates.

- The standard defines recycled coarse aggregate as the fraction recovered from construction demolition, precast concrete items and hardened concrete waste (or materials obtained from washing fresh concrete waste) crushed in an off-site processing plant.

- Mixed coarse aggregate corresponds to the coarse fraction composed of a mixture of aggregates (natural or composed aggregate, composed rocks and recycled aggregates).

- The standard incorporates the possibility of using recycled and mixed coarse aggregates for up to 20% of the total aggregates of the concrete produced.

- These recycled coarse aggregates can be used in plain or reinforced concretes of quality class H-30 or lower (maximum allowable characteristic strength of 30 MPa).

- Studies must be carried out to demonstrate their suitability under different conditions.

- The standard sets general criteria for mortars and concretes without differentiating between structural and non-structural performance.

- It is considered acceptable to use recycled aggregate in concrete in environments with type A1, A2, A3, M1, Q1 and C1 exposure levels set by CIRSOC 201:2005 Regulation[4]. Tests and measures are required according to the type of exposure.

4. Exposure levels are set out in Chapter 2 of CIRSOC 201:2005 in Tables: 2.1. General exposure classes leading to reinforcement corrosion; and 2.2. Specific exposure classes which may lead to degradation other than reinforcement corrosion.

2. IRAM 1512:2013. FINE AGGREGATE FOR CEMENT CONCRETE.

- This standard defines the use of natural or crushed fine aggregates, i.e., it does not cover the incorporation of recycled or mixed aggregates.

- As with the standard IRAM 1531, no specific criteria are set for mortar and concrete based on the intended use (structural or non-structural).

CEMENT AND POSSIBLE MINERAL ADDITIONS

• CURRENT SITUATION - TECHNICAL STANDARDS FOR CEMENT

As discussed above, current IRAM standards differentiate between general-purpose Portland cements, cements with special properties, and cement used to produce concrete for roadways made with high-performance pavers (refer to **table 1**). Standard IRAM 50000 indicates that clinker-based cements can be used in structural and non-structural works.

Table 1
Current cement standards.

Current IRAM standard	Application
50000: 2017 (including mod. 2019)	General-purpose cement.
50001: 2019 (including mod. 2020)	Cement with special properties.
50002: 2009 (including mod. 2017)	Cement used to produce concrete for roadways made with high-performance technology.
50003:2017	Cement. Conformity assessment.
1685:2019	Masonry cement.

Source: Information based on data from the IRAM Documentation Centre. 2021.

1. IRAM 50000: 2017 (MOD. 2019). GENERAL-PURPOSE CEMENT

Mineral additions described in this standard are permitted in the proportions indicated (refer to **table 2**). The additive content may be reduced by the percentage of minor constituents, but not the clinker and calcium sulphate content (refer to Table 1, Note 1, IRAM 50000).

Table 2
Tipos de cementos y componentes Norma IRAM 50000:2017 mod. 2019.

Type of cement	Component		
	Clinker + calcium sulphate	Additions	Minor constituents
Normal Portland cement	100-95	-	0-5
Portland cement with calcareous filler	94-75	6-25 – Calcareous filler	
Portland cement with slag	94-65	6-35 - Slag	
Composite Portland cement	94-65	(2 or more additions) 6-35 - Pozzolana and/ or siliceous fly ash + slag + filler and with ≤ 25 calcareous filler	
Pozzolanic Portland cement	85-50	15-50 Pozzolana or siliceous fly ash	
Blast furnace slag cement	64-25	36-75 - Slag	

Source: Information extracted from IRAM 50000 standard.

- Permitted mineral additions: Pozzolana, siliceous fly ash, granulated blast furnace slag and calcareous filler.

- Minor constituents:

  » A maximum of 5% of minor constituents is permitted.
  » These are finely ground natural minerals or minerals derived from the clinker manufacturing process or mineral additions (slag, calcareous filler, natural or industrial pozzolans) that may be added when manufacturing cement.

Some mineral additions do not require grinding as the production process provides suitable fineness.

- They can help to improve properties such as workability or water retention. They can be inert or have partial hydraulic properties (latent hydraulic or light hydraulic) or have pozzolanic properties..

- The standard states that the cement composition must be disclosed if requested by the user, except the minor constituents.

2. IRAM 50001:2019 (MOD. 2020). CEMENT WITH SPECIAL PROPERTIES.

- The standard deals specifically with cement that has one or more of the following special properties in addition to any of the previous classifications:

Name
High Initial Strength - ARI
High Sulphate Resistance - ARS
Moderate Sulphate Resistance - MRS
Low Heat of Hydration - BCH
Resistance to Alkali-Aggregate Reaction - RRAA
White - B

The Abbreviations refer to the Spanish term and are defined by the Argentinian norm.
Source: Information based on data from the IRAM Documentation Centre. 2021.

- The cement composition is as per the requirements of IRAM 50000 with additional special requirements according to the properties.

3. IRAM 50002:2009 AND MOD. 2017.

- This standard sets out the requirements for cement used to produce concrete to design and build roadways using high-performance technologies and slip-form pavers.

- Mineral additions for these cements are limited to a maximum of 20% (refer to **table 3**).

- The addition of minor constituents is permitted up to a maximum of 5%. As noted above, this percentage is deducted from the additive content, not from the clinker and calcium sulphate content.

- These cements provide advantages for pavements that need to be replaced or repaired quickly (fast track), for high-strength concrete, and when using slip-forms.

Table 3
Types of cement and components in IRAM 50002:2009 standard, mod. 2017.

Type of cement	Component		
	Clinker + calcium sulphate	Additions	Minor constituents
Normal Portland cement	100-95	-	0-5
Portland cement with calcareous filler	94-80	6-20 – Calcareous filler	
Portland cement with slag	94-80	6-20 - Slag	
Composite Portland cement	94-80	(2 or more additions) 6-20 - Pozzolana or siliceous fly ash + slag + filler	
Pozzolanic Portland cement	85-80	15-20 Pozzolana or siliceous fly ash	

Source: Information extracted from IRAM 50002 standard.

4. IRAM 1685:2019. MASONRY CEMENT.

- This standard deals with cements that combine the use of clinker with other products to improve workability, fluidity and water retention for masonry work (non-structural).

- They must meet physical requirements regarding setting time, fineness, volume stability, water retention, and incorporated air, in addition to mechanical requirements regarding compressive strength, although the requirements are not stringent (≥4.5 MPa on mortar prisms at 28 days).

- This standard does not set out composition requirements for masonry cement.

- It should be noted that under CIRSOC 501:2007 Regulation: "Argentinian Regulation on Masonry Structure", masonry cement is not intended for structural use.

- Masonry cement can be used for bedding mortars in non-reinforced joints. The use of rendering mixtures (plaster, cladding, etc.) not covered by CIRSOC 501 is not prohibited.

PUBLIC WORKS

• CURRENT SITUATION REGARDING SPECIFICATIONS

- The common goal of public works is to improve people's quality of life, particularly improving accessibility in poorer areas. National plans for road works, infrastructure and housing are under development. These include a Strategic Plan for Territorial Development and a Platform for Public Works and Projects. It is estimated that 37% of the concrete used in construction projects is used for public works.

- The National Directorate of Roads of Argentina (DNV) has issued the following specifications regarding concrete works:

  » General technical specifications for concrete pavements (DNV, 2017).
  » General technical specifications for concrete pavements using recycled concrete (DNV, 2017).

- Both specifications state that the materials must be suitable for stress levels according to the Traffic Classification Table 2 (traffic indices: T1, T2, T3 and T4).

- The DNV specification on concrete use states that crushed materials may contain aggregates from:

  » Structural concrete construction, demolition, renovation and repair works.
  » Precast structural concrete items crushed at the plant.
  » Crushed remains of unused hardened ready-mixed concrete.
  » Recovered at processing plant by washing fresh concrete waste that is made with mixed coarse aggregate.

- » If there is insufficient background information on recycled concrete, tests must be carried out to demonstrate suitable performance.
- » Recycled coarse aggregate is allowed up to the limit included in standard IRAM 1531 (maximum of 20%). However, the limit may be exceeded by 5% with prior authorisation from the Site Supervisor.
- » The use of recycled fine aggregate is not permitted.

CONCRETE REGULATIONS AND STANDARDS

• CURRENT SITUATION REGARDING SPECIFICATIONS

▪ "CIRSOC 201:2005 Regulation, the Argentinian Regulation on Concrete Structures" is currently in force and has a national scope. It came into force in 2013 and its application has been gradually expanding to different jurisdictions of the country since then.

▪ The regulation applies to structural concrete used for dwellings, garages, public premises, warehouses and industries, with a mass per unit of volume between 2 000 and 2 800 kg/m^3. It does not apply to non-structural works.

▪ The regulation does not allow for recycled aggregates to be added to structural concrete.

▪ It refers to other standards in force, however regulatory changes mean that it refers to outdated ones.

- » There are versions of the IRAM 1666 standard (RAM 1666 - 1, 2 and 3) that have not been in force since 2020. IRAM 1666 was updated and consolidated in 2020.

▪ IRAM 1666:2020 contains concrete classes that have been updated to higher strength performance values. It includes a broader list than that included in the CIRSOC 201:2005 classification of concrete types and qualities. The latter is now outdated.

▪ Another regulation is "CIRSOC 501:2007, the Argentinian Regulation on Masonry Work". This regulation does not currently allow for recycled aggregate to be used, nor does it contemplate different performance levels.

ECO-EFFICIENCY DESIGNATIONS FOR MORTAR, CONCRETE AND THEIR COMPONENTS

• CURRENT SITUATION

- The AAHE has members from the ready-mix concrete industry, suppliers of consumables and raw materials, equipment and machinery suppliers, specific media outlets, and associated professionals.

- As reported at the meeting with the IREK II team, around 200 to 250 concrete manufacturing companies in Argentina are members of the AAHE. The exact number is not available from the statistical reports published up to 2019.

- According to the 2015-2019 statistical report, associated concrete manufacturing companies produced 5 436 186 m^3 of concrete in 2019, and 48.6% of these companies are located in Buenos Aires and the surrounding metropolitan area.

- A significant number of companies using cement and producing concrete do not currently apply technologies and controls that focus on the final product quality.

- There are also companies that manufacture non-structural mortar and concrete or by-products for ancillary works.

- The use of technologies that result in a lower degree of aggressiveness towards the environment and that reuse by-products that would otherwise become waste of little economic and technological value needs to be improved.

- Product certifications on their technological and performance characteristics are available and the INTI plays a fundamental role in this area.

- Government departments are studying the possibility of introducing new policies associated with production issues.

- Demolition-related processes are currently relatively informal. In most cases there is no proper segregation between different waste streams and greater traceability is required.

- While there are waste recycling plants, a specific classification would be required for construction waste for it to be recovered and reused.

- The industrialisation of the concrete industry and the production of parts in industrial plants contribute to better controlling of delivered products. However, greater industrialisation would be required to maximise the use of recycled aggregates.

LOCAL GOVERNMENT BUILDING AND/OR CONSTRUCTION REGULATIONS

• CURRENT REGULATORY SITUATION IN LOCAL GOVERNMENT

▪ In Argentina, there are provincial and municipal regulations and standards. The national concrete regulation CIRSOC 201:2005 is generally taken as a reference, although it is not yet applied throughout the country. Local approval of this regulation is required. Some provinces that have approved the regulation are Tucumán (2006), Mendoza (2007), Salta (2008), and Buenos Aires (2021), among others[5].

▪ The CIRSOC 201 M: 96 Regulation on the "Design, calculation, and construction of reinforced, prestressed concrete structures for private municipal works" is currently in forcein the Autonomos City of Buenos Aires (INTI CIRSOC, 2001), but it is now outdated as noted above.

▪ These regulations adopt IRAM standards as conformity assessment parameters.

▪ Quality control guidelines on sustainable materials and construction processes which tend to improve the life cycle of buildings need to be included.

▪ Furthermore, incentives and deterrents are required for solutions to be used that improve the environmental footprint of buildings, take safety criteria into account based on the type of building use and application, and provide more efficient resource use.

MAIN CONDITIONS RELATED TO THE USE OF RECYCLED CONCRETE

• BUSINESS MANAGEMENT

▪ Few concrete manufacturers in Argentina apply the technical standards with third party certification, particularly IRAM 1666.

▪ Waste management on construction and demolition sites is poor and construction waste is not sorted.

▪ A low proportion of recycled concrete is used in concrete production.

▪ There is little to no information in the production and service sectors on the use of technologies that use waste as an input for other construction products. There is also a lack of training for construction personnel on all levels.

5. https://www.inti.gob.ar/areas/servicios-industriales/construcciones-e-infraestructura/cirsoc/reglamentos

- The type of recycled concrete, its intended use and characteristics are not well-defined, discouraging its use.

- Life cycle analyses of the product and its maintenance with a circular economy perspective are rarely carried out.

- Low barriers to entry. The investment and technical requirements to set up a ready mixed concrete plant are low compared to other industries.

- Very low penetration of quality management system (ISO 9001) and environmental management system (ISO 14001) certifications in the sector.

REGULATORY

- Standards and regulations do not promote, or only mildly encourage, the use of construction waste in the production chain.

- Technical standards focus on cement and concrete composition rather than functionality, causing barriers to emission reduction and resource efficiency.

- Regulations are outdated, particularly the CIRSOC 201:2005 Regulation on reinforced concrete structures.

- Different levels of public management (national, provincial and local) are involved in developing, applying and enforcing the standards; several scenarios are created across these different levels that do not contribute to the use of recycled concrete.

• MARKET

- There is little to no recognition of sustainable products, although there is a growing tendency to recognise and value them.

- Economic crises provide opportunities to explore initiatives that reduce production costs without detracting from product attributes.

- Financing/incentives are required to develop technological processes and productivity improvements focussed on resource efficiency and GHG emission reduction.

- User requirements are poorly or incompletely specified to the supplier.

- Ready mixed concrete procurement processes are almost exclusively based on the price per cubic metre. Limited control monitoring upon reception.

• STRUCTURAL

▪ The distance from the cement and concrete industries to the place where the products are used and the corresponding logistics have a large impact on product cost and carbon footprint.

▪ The construction sector is highly informal.

▪ The construction recycling market is highly informal.

▪ Construction waste is informally and illegally disposed of as fill and/or sent to landfills or dumps, thereby being wasted.

▪ Construction waste is poorly sorted, if at all, which limits or hinders the possibility of recycling higher value fractions.

▪ Low disposal costs limit the interest in using construction or demolition waste as an input to generate other materials.

▪ There is no federal network of technical assistance and testing services to help local concrete manufacturers and users to improve their technical capacities and to control the concrete received on site.

3

Key players

Stakeholders from the private and public sectors involved in the cement and concrete industry (including people from academia, technical institutions and workers' associations) were screened as part of the process to develop the proposal. From there, meetings and interviews were held with the different groups aimed at exchanging information and ideas, gathering contributions from the different sectors, identifying the challenges and opportunities from each perspective, and validating the consolidated proposal.

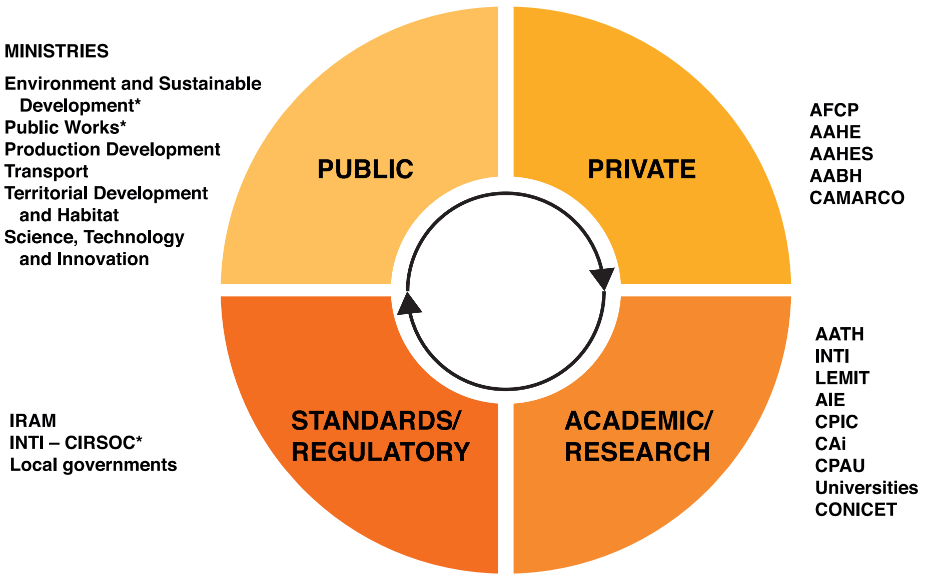
PLAN RECIPIENTS

- Ministry of the Environment and Sustainable Development - Argentina.
- Ministry of Productive Development - Argentina.
- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety - Germany.

• KEY PLAYERS IN THE PROCESS

A map of key players by sector is presented below. Those considered a priority for the Plan development and consultation process have been highlighted.

Figure 9
Map of key players by sector.
Industrial production of Portland cement (AFCP).



(*) Players involved in the consultation process.

Players
relevance
H = High,
M = Moderate
L = Low

▶ **Government**
- Ministry of the Environment and Sustainable Development **H**.
- Ministry of Productive Development **H**.
- Ministry of Public Works **H**.
- Ministry of Transport **M**.
- Ministry of Territorial Development and Habitat **M**.
- Ministry of Science, Technology, and Innovation **M**.

▶ **Entities related to technical standards and regulations**
- Argentine Institute for Standardisation and Certification - IRAM **H**.
- National Industrial Technology Institute (INTI), Research Centre of National Safety Regulations for Civil Works (CIRSOC) **H**.

▶ **Business associations**
- Association of Portland Cement Manufacturers (AFCP) **H**.
- Ready Mixed Concrete Association of Argentina (AAHE) **H**.
- Structural Concrete Association of Argentina (AAHES) **M**.
- Concrete Block Association of Argentina (AABH) **M**.
- Argentine Chamber of Construction (CAMARCO) **M**.
- Argentine Chamber of Mining Entrepreneurs (CAEM) L.
- Chamber of Stone of the Province of Buenos Aires L.

▶ **Professional associations**
- Professional Council of Civil Engineering (CPIC) **H**.
- Professional Council of Architecture and Urban Planning (CPAU) **M**.
- Association of Engineers of the Province of Buenos Aires (CIPBA) **M**.
- Argentine Centre of Engineers (CAI) **M**.

▶ **Technical and technological institutions**
- Argentinian Concrete Technology Society (AATH) **H**.
- Association of Structural Engineers (AIE) **H**.
- National Industrial Technology Institute (INTI) **H**.
- Multidisciplinary Training Laboratory for Technological Research (LEMIT) H.
- National Scientific and Technical Research Council (CONICET) **M**.
- University system **H**.

▶ **Guilds and trade unions** (when disseminating the plan and training players from the production sector).
- Argentinian Building Workers Union (UOCRA) **M**.
- Argentinian Mining Workers Association (AOMA) **M**.

Suppliers of raw materials and finished products
- Cement companies.
- Concrete manufacturing companies.
- Chemical additives and fibre companies.
- Mineral additive suppliers: blast furnace slag, silica fume, pozzolana.
- Precast manufacturers.
- Aggregate suppliers.

3

Development of the plan

1

Vision

Towards 2030, Argentina is respected by its peers for driving the development of a more decarbonised building materials industry through resource and material efficiency strategies, particularly focussing on cement and concrete.

Baseline criteria and instruments to implement the plan.

The Plan is centred around promoting greater resource efficiency. This is mainly done by recycling concrete and other building materials and increasing the use of recycled coarse and/or fine aggregate and recycled cement fines in concrete manufacturing. The instruments to achieve this are presented below. These instruments are intended to be independent of each other, but they can be complementary or even applied simultaneously.

The impact and emission reduction calculations were performed using baseline information from AFCP and AAHE on the respective volumes of cement and concrete manufactured in 2019. Assumptions were applied for each measure based on the volume of concrete that is expected to be manufactured in 2030. Specifically, the values taken for the impact and emission reduction calculations are summarised in the following table. The sources of these values can be found in APPENDIX I "Sources of data and information used for the analysis".

- 1% reduction in clinker factor = **0.009 t CO_2/t cement** (Source: IPCC).
- 1% reduction in clinker factor = **0.547 t total CO_2 emissions (0.519 direct + 0.028 indirect)** (Source: AFCP).
- 1 t of cement with clinker factor 65 = **0.502 t CO_2** (estimated)[6].

6. Estimated value towards 2030 based on a reduction of the clinker factor from 70 to 65 as a consolidated value. This estimate is compatible with the AFCP's strategic objectives. Clinker factor, based on the criteria adopted in category "092a Equivalent Clinker/Cement Factor from GNR (Getting the Numbers Right) protocol version 3.1". (GCCA) https://www.cement-co2-protocol.org/en/ Date: 15-11-21

- Recycled concrete incorporates 30% recycled coarse aggregate = reduction of **0.019 tonnes CO_2/m^3** concrete.

  » 1 m^3 of traditional concrete emits **0.149 t CO_2** (Source: ICPA).
  » 1 m^3 of concrete made with 30% recycled coarse aggregate emits **0.130 t CO_2** (Source: ICPA).

As an example, a mixture made with 135 kg/t concrete for approximately 1 100 kg of aggregates is assumed to emit 149 kg of CO_2 per m^3 of concrete.

If 30% of the coarse aggregate in the mixture is replaced with recycled aggregate, in this example the emissions are reduced to 130 kg of CO_2 per m^3 of concrete. (ICPA, 2014)[7], CPIC (2017)[8], (Blanco-Carrasco, Hornung, and Ortner, 2010)[9]. Depending on the performance required, crushed aggregates are usually used in structural concrete. These aggregates are obtained from open-pit quarries.

Aggregate production involves blasting operations, internal transport, crushing, and sorting. Concrete manufacturing processes also require internal transport, handling, and mixing.

- Cement production in 2019 – **11 923 660 t** (Source: AFCP)

- Concrete production (AAHE members and non-AAHE members and others) in 2019 – **10 872 372 m^3** (estimate based on AAHE data).

7. The Cement Industry and Sustainability. Table comparing the characteristics of traditional and "green" concrete. Contribution to CO_2 emissions. Source: https://web1.icpa.org.ar/wp-content/uploads/2019/04/La-industria-del-cemento-y-la-sostenibilidad-V-DIGITAL.pdf [Date accessed: 31-08-2021].
8. Sustainable Concrete in Argentina. State of the Art and Good Practise. Chapter on sustainable concrete production and use. The Cement Industry and Sustainability. Source: https://issuu.com/documentoscpic/docs/cpic-hormigon-baja [31-08-2021] P. 53
9. Blanco-Carrasco, Hornung, and Ortner (2010). Qatar: Green Concrete Technologies. Towards a Sustainable Concrete Industry in Qatar. Source: https://issuu.com/oconsult/docs/towards_a_sustainable_concrete_industry 31-08-2021]. P. 22.

2

Strategy instruments

SUMMARY OF PROPOSED INSTRUMENTS

Table 4
Proposed instruments.

Measure	Description of instruments
1	Update IRAM 1531 and 1512 concrete standards to include recycled aggregate and develop a new standard for recycled aggregates.
2	Update IRAM 50000, 50001, 50002 and 1685 cement standards or develop a new standard for mineral additions.
3	Increase the use of recycled concrete in public works.
4	Incorporate an increased use of recycled concrete and cement with mineral additions in CIRSOC regulations.
5	Contribute to developing a sustainable production seal for recycled concrete and cement.
6	Incorporate the use of recycled concrete and cement with mineral additions into local government building and construction regulations.

PRIORITISATION AND IMPACT MATRIX

▸ To build the matrix we analysed the selected the measures by determining:

» The estimated time required to implement the measure.
» The estimated annual CO_2eq emission reduction target to be expected by 2030.
» The estimated investment required to implement the measure.
» The cost/benefit ratio expressed in dollars per tonne of Co_2eq per year.
» The priority of the measure according to the difficulty of implementing it at low, medium and medium-high ranges.

Table 5

Prioritisation and impact matrix.

Measure	Instruments Description	Implementation time (years)	Emission reduction target (t CO_2/year)[10]	Implementation cost (dollars/year)	Cost/ benefit ratio (dollars/t CO_2)	Implementation difficulty
1	Update IRAM 1531 and 1512 concrete standards to include recycled aggregate and develop a new standard for recycled aggregates.	0.5 - 1	93 000	36 000	0.39	Low
2	Update IRAM 50000, 50001, 50002 and 1685 cement standards or develop a new standard for mineral additions.	1 - 2	537 000	90 000	0.17	Medium
3	Increase the use of recycled concrete in public works.	1 - 2	14 000	54 000	3.86	Low
4	Incorporate an increased use of recycled concrete and cement with mineral additions in CIRSOC regulations.	2 - 5	21 500	150 000	6.98	Medium-high
5	Contribute to developing a sustainable production seal for recycled concrete and cement.	2	72 000	54 000	0.75	Low
6	Incorporate the use of recycled concrete and cement with mineral additions into local government building and construction regulations.	3 - 5	15 500	150 000	9.68	Medium-high

10. This involves an estimate of the effort required (professional/institutional fees) to produce studies, technical documents and/or proposals to help implement the corresponding measure.

3

Measure Development Guidelines

Measure 1

Update IRAM 1531 and 1512 concrete standards to include recycled aggregate and develop a new standard for recycled aggregates

Table 6
Summary of current aggregate situation.

IRAM STANDARDS	SPECIFICATIONS
1531:2016	• Allows up to 20% of recycled and mixed coarse aggregates to be used. • Requires suitability studies. • Concrete quality up to H-30 (plain or reinforced concrete). • Does not differentiate between structural and non-structural use. • Exposure levels A1, A2, A3, M1, Q1 y C1.
1512:2013	• No permite uso de reciclados. • No diferencia uso estructural u otro uso.

Concrete class:

- Concrete classes from H-15 to H-60 are defined in **table 2.7** of CIRSOC 201:2005 regulation. Concrete strength. Structural concrete belongs to classes ≥H-20.

- **Table 6** of IRAM 1666:2020 standard on concrete strength classes defines concrete quality classes from H-5 to H-100. The same criterion of ≥H-20 is adopted.

PROPOSED STRATEGY

- **Update the existing aggregate standards** to expand the possibilities of using recycled aggregate in concrete.

- **Optionally develop a specific recycled aggregate standard** contemplating recycled aggregate use in mortar, concrete, and other uses such as granular soils, improved soils, and paving bases.

1. IRAM 1531 PROPOSAL FOR COARSE AGGREGATE

- **Establish different characteristics depending on performance or use** (structural and non-structural) and whether the aggregate is to be used for plain unreinforced concrete or reinforced concrete.

Table 7
Allowable percentage of coarse aggregate based on structural and non-structural use.

CONCRETE CLASS	LIMIT VALUES FOR THE USE OF RECYCLED COARSE AGGREGATE	
	Maximum (% by weight)	USES
H-10 or lower	100	Non-structural. Plain unreinforced. Minor works without structural performance and other uses including granular bases, fills, urban furnishings.
> H-10 and ≤ H-15	70	Non-structural. Plain unreinforced. Minor works, public works, urban furnishings, pavements, underground pedestrian traffic, precast construction items (e.g. blocks and cladding panels).
> H-15 and ≤ H-25	50	Plain unreinforced and reinforced. Non-structural and structural (≥ H-20). Structural civil works, pavements, public infrastructure.
> H-25 and ≤ H-35	30	
> H-35 and ≤ H-45	20	
> H-45 and ≤ H-60	10	Plain unreinforced and reinforced. Works with parameters such as modulus of elasticity related to quality and performance on site.
> H-60	5	

NOTES:

A. The table specifically applies to the use of mixed and recycled aggregates in mortar and plain and/or reinforced concrete.

B. Concrete suppliers should assess the possibility of incorporatingmixed or recycled aggregate in concrete with quality classes above H-35.

C. The modulus of elasticity or other suitability studies related to the type of project should be specified for concrete with classes of H-45 and above to ensure the quality and performance of the specified concrete. For example: permeability due to water penetration, capillary suction, drying shrinkage, wear, potential reactions due to aggressiveness such as alkali - aggregate reaction (AAR), freezing and thawing, etc.

D. Suppliers of prestressed concrete must perform studies which ensure that the concrete will comply with the specified quality and performance requirements.

E. Recycled aggregates can be used in cementitious mortars applied to construction products such as tile sub-bases, ready-mixed mortars used for masonry work, precast items, etc.

F. With regard to structural masonry work, the CIRSOC 501:2007 Regulation does not specify if recycled aggregate can be used. Therefore, additional comparative studies should be performed to ensure the mortar used would comply with the required performance and specifications.

2. IRAM 1512 PROPOSAL FOR FINE AGGREGATE

- Up to 30% of the total aggregate volume can be incorporated in concrete with quality classes of H-30 or lower for structural use.

- Up to 100% of recycled aggregate can be used for non-structural concrete of quality class H-10 or lower.

- In other cases, the supplier should perform additional studies to ensure the concrete is suitable and of the required quality for the type of work.

- In the case of structural concrete, additional parameters should be defined such as the modulus of elasticity or other suitability studies relating to concrete durability. For example: permeability due to water penetration, capillary suction, drying shrinkage, wear, potential reactions due to damage from alkali - aggregate reaction (AAR), freezing and thawing, etc.

Table 8
Allowable percentage of fine aggregate based on structural and non-structural use.

CONCRETE CLASS	LIMIT VALUES FOR THE USE OF RECYCLED FINE AGGREGATE	
	Maximum (% by weight)	USES
H-10 or lower	100	Non-structural. Plain unreinforced. Minor works without structural performance and other uses including granular bases, fills, urban furnishings.
> H-10 and ≤ H-15	50	Plain unreinforced. Non-structural. Minor works, public works, urban furnishings, pavements, underground pedestrian traffic, precast construction items (e.g. blocks and cladding panels).
> H-15 and ≤ H-30	30	Plain unreinforced and reinforced. Structural. Structural civil works, pavements, public infrastructure.

APPLICATION ACCORDING TO ENVIRONMENTAL CONDITIONS

Coarse and fine aggregates can be used based on additional studies according to the environmental conditions of where the product is to be used. Refer to **table 9** detailing the comparative differences between the current and the proposed situation.

In the case of mortar and concrete for non-structural use, aggregates can be used up to the limits set out in the table.

- There are no application limits relating to corrosion exposure for non-structural unreinforced concrete with quality class ≤H-20.
- Structural concrete must strictly comply with the strength and durability conditions according to the exposure levels set out in the regulations.
- The necessary studies shall be performed to ensure the quality and suitability of the structures in service.

- The modulus of elasticity or other suitability studies related to the type of project should be specified for concrete with classes of H-45 and above to ensure the quality and performance of the concrete used.

Table 9
Comparison of current and proposed situation.

Guideline characteristics	Current	Proposed ranges						
Concrete class	< H-30	>H-60	>H-45-≤H-60	>H-35-≤H45	>H-25-≤35	>H-15-≤H-25	>H-10-≤H15	≤ H-10
Concrete use		Structural, plain and reinforced					Plain unreinforced	
A. Recycled coarse aggregate (% volume/total aggregate volume)	20	≤ 5	10	20	30	50	70	100
A. Recycled fine aggregate (% volume/total aggregate volume)	Not allowed	Not used			≤ 30		50	100
AAR (if applicable)	Verify	Verify					---	---
Static Modulus of Elasticity	---	Establish and verify			According to type of project		---	---
Exposure limit	A1, A2, A3, M1, C1, Q1	A1, A2, A3						
			M1, M2					
			C1					
				Q1				

ASSUMED IMPLEMENTATION SCENARIO

1. Background information

Aggregates in concrete	Concrete volume m^3	t CO_2eq/m^3 concrete	Source
Coarse aggregate	1	0.149	ICPA, 2015
Scenario with 30% of recycled coarse aggregate	1	0.130	ICPA, 2015
m^3 of concrete from AAHE members (emissions from coarse aggregate only)	5 436 186	809 992	AAHE, 2019
Estimated m^3 of concrete from non-AAHE members + construction companies + precast manufacturers	5 436 186	809 992	Estimate
Scenario with AAHE and non-AAHE concrete manufacturers + construction companies + precast manufacturers	10 872 372	1 619 984	Estimate

It is estimated that by 2030, 60% of AAHE member companies and 30% of non-member companies will apply the amended IRAM standard.

2. Emissions calculation based on assumed scenario

It is estimated that once the IRAM standards for coarse aggregates have been modified, 60% of AAHE members and 30% of non-AAHE members will produce concrete following these standards by 2030.

IRAM aggregates, average 30% of recycled coarse aggregate	Concrete volume m^3	t CO_2eq/m^3 concrete	Source
AAHE plants - assumed standard applied to 60% of concrete produced	3 261 712	0.019	61 973
Remaining plants - assumed standard applied to 30% of concrete produced	1 630 856	0.019	30 986
Total			92 959

SUMMARY

- **Proposal:** use maximum quantities of recycled aggregate depending on the concrete type and intended use.
- **Assumption:** 60% of AAHE member concrete manufacturing plants and 30% of non-member plants apply the standards and new maximums. This scenario only considers the use of up to 30% of recycled coarse aggregate.
- **Expected emission reduction:** 93 000 t CO_2eq/year.

Measure 2

Update IRAM 50000, 50001, 50002 and 1685 cement standards or develop a new standard for mineral additions.

Table 10
Summary of current cement situation.

IRAM STANDARDS	SPECIFICATIONS
50000 and 50001	• Clinker content ranges are set based on cement classification. • Mineral additions can be added with limit values based on cement classification. • Cement composition includes up to 5% of minor constituents. • The possibility of using concrete demolition waste as additions or minor constituents is not mentioned.
50002	• Clinker content ranges are set based on cement classification. • Up to 20% of mineral additions can be added with limit values based on cement classification. • Cement composition includes up to 5% of minor constituents. • The possibility of using concrete demolition waste as additions or minor constituents is not mentioned.
1685	• The possibility of using concrete demolition waste as additions or minor constituents is not mentioned.

PROPOSED STRATEGY

- Update IRAM 50000, 50001, 50002 and 1685 cement standards or develop a new standard for mineral additions.

  » The proposal is to update the standards by incorporating cementitious fines.
  » A new standard could optionally be developed to study the characteristics and requirements of cementitious fine mineral additions.

1. UPDATE IRAM 50000, 500001, 50002 AND 1685 STANDARDS

- Incorporate the possibility of using materials recovered from concrete demolition as part of the 5% of minor constituents.

- Incorporate as a type of recovered mineral additive.

- Develop a standard which defines the physical and chemical characteristics and requirements that recovered materials must meet to be used as a mineral additive. Establish traceability guidelines.

- In the case of masonry cements, allow an increased amount of additions as minor constituents of up to 15% subject to material feasibility and suitability studies. Where applicable, the cement must comply with the specified performance requirements regarding wear.

- The proposal is to reduce the clinker factor by 5%, taking it to 65% by weight for the different types of cement.

- In addition, 50-70% of recycled aggregates can be used in commercial masonry cement, subject to suitability studies that demonstrate suitable performance for the intended use.

Assumed implementation scenario

1. Background information

Clinker cement	Clinker factor	t CO_2eq/t cement	Source
Current	70	0.547	AFCP, 2019
For each reduced clinker factor point	1	0.009	IPCC, 2006; AFCP, 2019
AFCP 2030 target	65	0.502	Estimate

2. Emissions calculation based on assumed scenario

IClinker factor reduction for IRAM Cements (applies to 100% cement)	Cement [t]	t CO_2eq	t CO_2eq/year avoided
With clinker factor of 70	11 923 660	6 522 242	
If 100% of cement has a clinker factor of 65	11 923 660	5 985 677	
Total		5 985 667	536 565

SUMMARY

- **Proposal:** use maximum values of mineral additions including recycled materials depending on the cement type and intended use.
- **Assumption:** 100% of cement has a clinker factor of 65%.
- **Expected emission reduction:** 536.565 t CO_2eq/year.

Measure 3

Increase the use of recycled concrete in public works.

Table 11
Current situation: public works.

Tender specifications / standards	SPECIFICATIONS
GENERAL	• It is estimated that 37% of the concrete used in construction projects corresponds to public works. • Public works are aimed at improving accessibility in poorer sectors. • National plans under development (road works, infrastructure, and housing).
DNV	• There is a specification which allows the use of recycled concrete.

PROPOSED STRATEGY

- Update road work specifications (DNV) to include the requirements set out in strategic measures 1 and 2. The regulatory issues raised in measure 4 should also be considered.

- Update tender specifications for public works to incorporate recycled concrete and recycled aggregates; differentiate between structural and non-structural uses, minor and complementary works, works of art, and urban furnishings.

- Establish traceability guidelines for the recycled materials used and on-site controls.

- Include guidelines which give preference to State suppliers that use sustainable materials as part of supplier assessment plans (public tenders).

- An implementation scenario is proposed in which 50% corresponds to public works, of which 30% would come from AAHE member manufacturing plants and 45% from non-member plants.

ASSUMED IMPLEMENTATION SCENARIO

The production data indicated above has been taken as the base line. This measure is taken as an additional measure to measures 1 and 2.

Increase the use of recycled concrete in public works*	Concrete [m^3]	t CO_2eq /m^3 of concrete avoided	t CO_2eq/year avoided
AAHE plants - assumed standard applied to 30% of plants	301 708	0.019	5 732
Remaining plants - assumed standard applied to 45% of plants	452 562	0.019	8 599
Total			14 331

** It is assumed that 37% of concrete produced corresponds to public works*

SUMMARY

- **Proposal:** incorporate maximum values of recycled aggregate to tender specifications for public works depending on the concrete type and intended use.
- **Assumption:** applied to 50% of public works. 30% of AAHE member concrete manufacturing plants and 45% of non-member plants apply the new maximums.
- **Expected emission reduction:** asciende a 14 000 t CO_2eq/year.

Measure 4

Incorporate an increased use of recycled concrete and cement with mineral additions in CIRSOC regulations.

Table 12
Current situation regarding regulations.

Tender specifications / standards	SPECIFICATIONS
IRAM 1666:2020 CIRSOC 201:2005	• Regulates concrete for structural use. Does not apply to non-structural works. • Includes outdated standards such as IRAM 1666-1, 2 and 3. The standard has been updated and consolidated in 2020. • IRAM 1666 contains concrete classes that have been updated to higher strength performance values. • These values do not match the concrete types and qualities set out in the CIRSOC Regulation 201:2005. The latter is now outdated. • The Regulation and the Standard do not differentiate between structural and non-structural works. • The Regulation does not mention the possibility of using recycled aggregate. • CIRSOC 201:2005 was approved several years after it was designed, entering into force in 2013. It is mandatory for public works.
CIRSOC 501: 2007	• It is intended for structural masonry work. • The Regulation does not mention the possibility of using recycled aggregate. It should be updated and a differentiation should be made based on performance.

PROPOSED STRATEGY

- Update regulations to include an appendix on recycled concrete in the following:

  » Chapter 3 Materials: proposed changes to IRAM aggregate and IRAM cement standards (refer to measures 1 and 2).
  » Chapter 4: quality management requirements for manufacturing plants, requirements on the use of recycled aggregate and controls.
  » Study the influence of using recycled concrete in extreme climates (hot and cold), including conditions to use in structural concrete.

- Another option is to put forward a document or guide which allows recycled aggregate to be used in concrete by stipulating specific performance assessment guidelines according to the required type of performance.

- A future scenario is proposed where the assumption applies to 75% of public works, of which 30% would come from AAHE member manufacturing plants and 45% from non-member plants.

ASSUMED IMPLEMENTATION SCENARIO

The production data indicated above has been taken as the base line. This measure is taken as an additional measure to measures 1 and 2.

Incorporate an increased use of recycled concrete and cement with mineral additions in CIRSOC regulations*	Concrete [m^3]	t CO_2eq/m^3 of concrete avoided	t CO_2eq/year avoided
AAHE plants - assumed standard applied to 30% of plants	452 562	0.019	8 599
Remaining plants - assumed standard applied to 45% of plants	678 844	0.019	12 898
Total			**21 497**

** It is assumed that 37% of concrete produced corresponds to public works.*

SUMMARY

- **Proposal:** incorporate maximum values of recycled aggregate in regulations depending on the concrete type and intended use.
- **Assumption:** applied to 75% of public works. 30% of AAHE member concrete manufacturing plants and 45% of non-member plants apply the new maximums.
- **Expected emission reduction:** 21 500 t CO_2eq/year.

Measure 5

Contribute to developing a sustainable production seal for recycled concrete and by-products.

Table 13
Current situation: acknowledgements and awards.

AAHE	• Approximately 250 member companies in 2019. • Associate manufacturing companies produced 5 436 186 m^3 in 2019. 48.6% of these companies are located in Buenos Aires and the surrounding metropolitan area. • Demolition processes tend to be relatively informal. Greater traceability is required. • There are recycling plants, but specific construction waste sorting is required.
Product certifications	• Product certifications are carried out in terms of technology and performance. The INTI plays an important role in these certifications. They are applied to cement for example. • Self-declarations can be made regarding product sustainability.
Government eco-efficiency recognition	• There are no eco-efficiency recognitions or awards at the moment. However, the government expects to have them in the future. • Policies are needed that value efficient resource use by suppliers and in construction.

PROPOSED STRATEGY

- Develop a Sustainable Production Seal to be applied to concrete and products made using recycled mortar and concrete.

- Assessment and qualification implies complying with the requirements to incorporate recycled materials in mortar and concrete, to use resources carefully during manufacturing, to implement quality controls, and to ensure that resources are reused.

- Raise awareness and disseminate information on how to use resources efficiently, how to reuse them, and how to improve the life cycle of materials, particularly concrete and consumables used to make concrete.

- An improvement in the life cycle would mean the works have greater durability. As a result, fewer maintenance and repair activities are required which imply costs, further use of resources and technologies, and even impact on safety.

- Define an assessment or audit process to obtain the seal, to be carried out by an assessment body which could be led by INTI.

- Include guidelines which give preference to State suppliers that use sustainable materials as part of supplier assessment plans (public tenders).

- In addition, public policies should be implemented that promote the use of technology during material production processes. Policies should also be put in place to create different ranges of recycling plants to reuse waste concrete and other products in construction projects.

ASSUMED IMPLEMENTATION SCENARIO

The production data indicated above has been taken as the base line. This measure is partly taken as an additional measure to measures 1 and 2.

Development of a Sustainable Production Seal	Concrete [m^3]	t CO_2eq /m^3 of concrete avoided	t CO_2eq/year avoided
AAHE plants - assumed standard applied to 50% of plants	2 718 093	0.019	51 644
Remaining plants - assumed standard applied to 20% of plants	1 087 237	0.019	20 658
Total			72 301

SUMMARY

- **Proposal:** develop a sustainable production seal for recycled concrete and cement that incorporates sustainability criteria (including maximum values of recycled aggregate in concrete) depending on the concrete type and intended use.
- **Assumption:** 50% of AAHE member concrete manufacturing plants and 20% of non-member plants apply the criteria.
- **Expected emission reduction: :** 72 000 t CO_2eq/year.

Measure 6

Incorporate the use of recycled concrete and cement with mineral additions into local government building and construction regulations.

Table 14
Current situation: local government regulations.

REGULATIONS	• There are local government regulations and standards in place across the country. • They usually take the national CIRSOC 201:2005 regulation as a reference, although this is not applied consistently across the entire country. This regulation must be approved at local level. • Regulation CIRSOC 201 M:1996 for municipal public works is currently in force for Buenos Aires. • The regulations need to be updated, as some of the referenced standards have been amended or replaced. • The concrete qualities mentioned are outdated and have been expanded in some cases in the IRAM 1666:2020 standard. • IRAM standards are adopted. • The use of sustainable materials such as recycled concrete and recycled components is not specified in the standards.

PROPOSED STRATEGY

- Promote the interconnection between ministerial and provincial programmes related to public works, public infrastructure and housing.

- Promote the incorporation of at least 30% of recycled concrete.

- Design and implement a training strategy in local plants on regulatory updates and proposals.

- Promote the use of recycling in non-structural and minor works.

- Perform feasibility studies on the use of recycled concrete in minor works in seismic zones.

- Quality control guidelines on sustainable materials and construction processes which tend to improve the life cycle of buildings need to be included to:

  » Preserve durability.
  » Minimise maintenance and repair activities.

- A scenario is proposed where the assumption is that 10% of AAHE member manufacturing plants and 5% of non-member plants will use recycled concrete.

ASSUMED IMPLEMENTATION SCENARIO

The production data indicated above has been taken as the base line. This measure is taken as an additional measure to measures 1 and 2. Measure 5 would assist in applying these measures.

Incorporation in local government building and/ or construction regulations	Concrete [m^3]	t CO_2eq /m^3 of concrete avoided	tCO_2eq/year avoided
AAHE plants - assumed standard applied to 5% of plants	543 619	0.019	10 329
Remaining plants - assumed standard applied to 10% of plants	271 809	0.019	5 164
Total			15 493

SUMMARY

- **Proposal:** develop and/or adapt chapters on recycled concrete and cement with mineral additions to be incorporated into local, provincial, and municipal construction and/or building regulations.
- **Assumption:** 10% of AAHE concrete manufacturing plants and 5% of non-member plants apply the criteria.
- **Expected emission reduction:** asciende a 15 500 t CO_2eq/year.

3

Implementation barriers

Barriers to implementing measures 1 to 6 detailed above may arise. This could limit how the new criteria are applied to reduce the impact of resource use and GHG emissions. The proposed measures must be addressed by particularly taking the following into account:

- Potential resistance from companies and the value chain due to cultural, technological and financial issues, among others.
- Regional differences in incorporating new technologies.
- Low availability of financial instruments and incentives for companies.
- Lack of consensus needed to implement some measures.
- Availability of concrete to be recycled in large urban centres and small towns.
- Informality of the construction recycling market.
- Poor management of construction waste on construction sites.
- Lack of information/knowledge regarding the possibilities/benefits of using recycled building materials.

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4

Roadmap

Activities that form the roadmap.

Key players from public, private, and academic sectors must be involved to develop and later implement the proposed measures. Several activities are required to overcome any barriers that may arise, and to accelerate cement and concrete companies implementing the measures. The view is to achieve the greatest possible impact in terms of resource efficiency and GHG emission reduction by 2030.

The proposed measures will not have an impact on their own; the goals will be achieved if the initiatives coexist and are all successful. The IRAM standards and CIRSOC Regulations must allow concrete manufacturers to increase their quality standards and good manufacturing practices, something that public policies must promote. There must be a constant flow of construction and demolition waste that is sorted, has stable characteristics, is cost efficient, and environmentally and climatically friendly.

Policies and instruments on public management, capacity building in companies and the construction ecosystem, knowledge creation and dissemination, among others, will be essential. Some of these activities are presented below, by way of example:

INCENTIVES

- To achieve sustainable production, resource efficiency, and a circular economy, making it easier for cement and concrete companies to incorporate recycled aggregate into their products.

- To research and develop technological solutions that increase resource efficiency and reduce GHG emissions.

- To create a market where decision making by investors, buyers, and users is done by prioritising sustainable products and lower GHG emissions.

REGULATIONS

- To update regulatory frameworks, such as those on construction waste management, and to recognise waste as by-products to be used in new production processes.

- To strengthen controls and sanctions to improve construction waste management, promoting greater use of the waste as consumables for production processes.

- To develop instruments that promote an increased use of waste building materials as raw materials for cement and concrete manufacturing.

MARKET

- To include guidelines which give preference to State suppliers that use sustainable materials as part of supplier assessment plans (public tenders).

- To include quality control guidelines for works with sustainable materials.

- To develop recognition schemes such as awards and other initiatives for products with higher proportions of recycled materials and companies that apply resource efficiency and emission reduction criteria.

- To make administrative procedures (such as construction project permits) easier for works that incorporate materials with higher proportions of recycled materials.

TECNOLOGY

- To develop technical studies that support the use of higher proportions of recycled materials in cement and concrete manufacturing.

- To promote research and development into sustainable materials and environmentally friendly construction processes by public organisations such as the INTI and universities.

INFORMATION

- To raise awareness on the responsible use of sustainable concrete and materials.

- To promote the sustainable consumption of cement and concrete made with higher proportions of recycled materials.

- To run awareness campaigns on the benefits of using higher proportions of recycled materials to manufacture cement and concrete.

- To promote resource-efficient practices in public infrastructure. For example, efficient use of consumables, by-products from demolitions, and by-products created during industrial and construction processes.

TRAINING

- For players in the value chain

  » For the construction industry and support services.
  » Specifically for SMEs.

- Workshops with sectoral and multi-sectoral representatives from the value chain.

5

Conclusions

The contribution of these measures to reducing GHG emissions is clear from the proposals we have presented. However, these measures are not the only ones that could contribute to reducing emissions. They complement other measures including those aimed at improving energy efficiency, increasing the proportion of renewable energy and/or alternative fuels, and carbon capture, which both cement and concrete companies have been exploring.

We consulted key players from the private, public, and academic sectors to develop these measures. This allowed a valid methodological approach to be followed to analyse the feasibility and scope of the measures. We also explored the requirements of the measures and their implementation barriers.

Some initial conclusions of the study suggest that:

- The implementation of the measures is feasible considering existing technology, technical possibilities, and economic viability.

- The potential emission reductions would have a high impact at a national level

Potential emission reductions

- **630 000 t CO_2eq / year**.
- This equates to **over 3% of emissions** in the industrial process sector.

- The government needs to be proactively involved in developing and implementing the measures.

- The proposed measures represent a technological leap which would have a direct impact on emission reductions and a positive social impact.

- The measures aim to reduce emissions, while also reducing pressure on the environment by reducing the need for virgin materials in quarries.

However, as with any proposal, some key issues must be addressed to overcome the identified barriers. Activities and initiatives must be carried out alongside one another to help accelerate the internalisation process within the production sector. Agreements should be built between the different players involved to work on these activities collaboratively.

Public and private stakeholders and society as a whole will need to be involved to implement a specific plan:

- In the private sector: production areas, consumable suppliers, construction companies, service organisations, chambers of commerce.

- In the academic and professional field: technical organisations, professional associations, universities and research centres.

- In the public sector: regulatory, production development, environment and sustainable development, innovation and technological development, and labour areas

The road ahead is challenging, but initiatives such as this one can surely help to improve the competitiveness of production sectors while lowering the impact on resources and climate change.

4

Appendices

1

Appendix I

SOURCES OF DATA AND INFORMATION USED FOR THE ANALYSIS

1. CEMENT

1.1. Cement clinker factor in Argentina. Current value 70%. P. 8.

- AFCP (2020). Report on Sustainability Indicators in Argentina's Cement Industry 2018-2019. Source: http://afcp.info/SOSTENIBILIDAD/Inf.Sostenibilidad_2018-2019_FINAL.pdf [31-08-21]

Notes:

- Average reduction of clinker factor in cement from 2010 to 2019 of 3%.
- In the table of consolidated indicators (P. 15)
- Clinker factor (%) is 70.3 in 2018 and 70.2 in 2019.
- Total CO_2 emissions (kg CO_2/t cement) of 556 in 2018 and 547 in 2019.
- Direct emissions in 2019: 519 (kg CO_2/t cement)
- Indirect emissions in 2019: 28 (kg CO_2/t cement)

1.2. Masonry cement clinker factor. Value: 64% P. 2.16.

- ·IPCC (2006). Guidelines for National Greenhouse Gas Inventories. Chapter 2. Emissions from the Minerals Industry. Source: https://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/vol3.html [31-08-21].

1.3. Production of cement for structural and masonry use.

Table 15
Table of consolidated indicators for the period. Cement production.

Cement production	2018	2019
Structural use (t)	11 841 500	11 081 728
Masonry (t)	925 174	841 932

- AFCP (2020). Report on Sustainability Indicators in Argentina's Cement Industry 2018-2019. Source: http://afcp.info/SOSTENIBILIDAD/Inf.Sostenibilidad_2018-2019_FINAL.pdf [31-08-21]

- CPIC (2017). Sustainable Concrete in Argentina. State of the Art and Good Practises. Source: https://issuu.com/documentoscpic/docs/cpic-hormigon-baja. [31-08-2021]. P. 21.

- For the calculations for 2019 we have used 547 kg CO_2/t with a clinker factor of 70%.

- Projection taking the information reported in **measure 1**:

  - **Clinker factor of 65%: 502 kg CO_2/t of cement.**

- AFCP (2020). Report on Sustainability Indicators in Argentina's Cement Industry 2018-2019. Source: http://afcp.info/SOSTENIBILIDAD/Inf.Sostenibilidad_2018-2019_FINAL.pdf [31-08-21]

- Ibero-American Cement Federation (Federación Iberoamericana del Cemento - FICEM): average gross CO_2 emissions worldwide equated to 633 kg CO_2/t of cement. In Argentina this figure was 640 kg CO_2/t of cement for the same year.

2. CEMENT

2.1. Emissions from concrete mixture.

COARSE AGGREGATES

- As an example, a mixture made with 135 kg/t concrete for approximately 1 100 kg of aggregates is assumed to emit 149 kg of CO_2 per m^3 of concrete.

- If 30% of the coarse aggregate in the mixture is replaced with recycled aggregate, in this example, the emissions are reduced to 130 kg of CO_2 per m^3 of concrete.

  - ICPA (2014). The Cement Industry and Sustainability. Table comparing the characteristics of traditional and "green" concrete. Contribution to CO_2 emissions. Source: https://web1.icpa.org.ar/wp-content/uploads/2019/04/La-industria-del-cemento-y-la-sostenibilidad-V-DIGITAL.pdf [31-08-2021] P. 29.
  - CPIC (2017). Sustainable Concrete in Argentina. State of the Art and Good Practises. Chapter on sustainable concrete production and use. The Cement Industry and Sustainability. Source https://issuu.com/documentoscpic/docs/cpic-hormigon-baja [31-08-2021] P. 53.

Notes:

Both bibliographies include the table which is originally from:

› M. Blanco-Carrasco, F. Hornung, and N. Ortner (2010). Qatar: Green Concrete Technologies. Towards a Sustainable Concrete Industry in Qatar. Source: https://issuu.com/oconsult/docs/towards_a_sustainable_concrete_industry [31-08-2021]. P. 22.
› Projection: 60% of AAHE member concrete manufacturing plants and 30% of non-member plants apply the updated standards.

2.2. Concrete production

Table of Annual Concrete Production from Member Concrete Companies as of December 2019.

Annual production	2018	2019
Concrete production [m^3]	5 677 752	5 436 186

- Ready Mixed Concrete Association of Argentina (AEHH) 2020. Summary of Annual Production and Production by Region 2015-2019. Accessed at web page https://hormigonelaborado.com/wp-content/uploads/2020/06/Producci%C3%B3n-2019.pdf [Date: 31-08-21].

7. Reduction of cement content by adjusting mixtures.

Mixtures incorporating recycled aggregates, reduction of water:cement ration, use of mineral and chemical additives.

Taking a traditional mixture with a cement content of 300 kg cement per m^3 of concrete.

- We have used 547 kg CO_2/t of cement for the calculations (refer to point 1.3).

- 0.3 t of cement equates to 0.174 t of CO_2 emissions per m^3 of concrete.

- A 5% reduction in cement content equates to a reduction of 0.0087 t of CO_2 emissions per m^3 of concrete.

- Advances in the use of chemical additives in sustainable concrete: https://gcpat.mx/es-la/about/news/blog/reducing-co$_2$-through-clínker-replacement

8. Recycled aggregates and concrete quality.

STANDARDS AND REGULATIONS IN DIFFERENT COUNTRIES.

It can be observed that the application of standards and regulations varies from country to country.

- •Alberte, E. P. V.; Handro, J. B. State-of-art review of current standards and specifications concerning recycled aggregates from CDW. Ambiente Construído, Porto Alegre, v. 21, n. 3, p. 305-320, jul./set. 2021. ISSN 1678-8621 Associação Nacional de Tecnologia do Ambiente Construído. Source: http://dx.doi.org/10.1590/s1678-86212021000300553 portuguese version.

2

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