INNOVATION IN THE CEMENT INDUSTRY
FOREWORD

The European cement industry is continuously researching ways to improve the quality of its products and reducing its environmental impact. It dedicates significant time and resources to innovation projects across a broad range of areas.

In this folder, we have highlighted just a few examples of such innovation and R&D projects. They all aim to improve our environmental performance, reduce CO$_2$ emissions and improve energy efficiency. These projects range from carbon capture and reuse in clinker manufacturing, development of low carbon cements and new binders and innovation in both concrete production and applications.

Why do we focus on innovation? Firstly, because our sector strongly believes that innovation drives our competitiveness and contributes to sustainable growth and job creation. Secondly, because the European cement sector is proud to be the world leader in different areas of innovation: over the past 20 years, we have consistently increased the use of alternative fuels (waste) in our kilns. Waste now accounts for 41% of our fuel needs. Also, by recycling its mineral content, we have significantly reduced our need for primary raw materials. This results in 18Mt of avoided CO$_2$ annually. This recycling of materials and recovering energy from a range of different waste streams is a unique example of industrial symbiosis, placing us at the heart of the circular economy. Thirdly, because our industry is committed to remaining in Europe. By investing in Europe, providing jobs to European citizens and adding value to Europe’s economy, we are maintaining a fully local cement and concrete supply chain. This supply chain provides jobs to 384 thousand people and adds €22 bn to the European economy. The final product in our supply chain is concrete. A material which is durable, energy efficient and resilient. A material which helps us build our homes, our roads, our public transport, our hydropower dams, our wind energy farms – the list is endless! Having a fully local supply chain means that our sector triggers a multiplier effect of 2.8 on the overall economy, meaning that for each EURO of added value generated in the cement and concrete industry, €2.8 of added value is added to the overall economy.

Our innovation efforts are also part and parcel of contributing to the climate change and energy efficiency goals of the European Union. In its Low Carbon Roadmap, CEMBUREAU has set out how it aims to reduce its CO$_2$ emissions by 32% by 2050 using conventional technologies and by 80% once breakthrough technologies such as carbon capture are successfully commercialized. The projects laid out in this folder formulate concrete responses to how the cement industry works towards achieving these goals.
The cement industry in Europe is creative and innovative. We know that there are many challenges to overcome. We look forward to a fruitful dialogue with policymakers on essential issues in order to achieve these objectives and access to public funding. These include:

- Time to market for R&D and innovation projects, including the important role of the standardization process;
- Availability of substitute materials: how can we ensure the continued supply of clinker substitutes such as slag from the steel sector and fly ash from the power sector (with the latter disappearing along with the decarbonation of the power sector);
- Economically justified payback time which is essential to maintain a healthy investment rate;
- Ensuring workers have the necessary skills and that proper education and training is available to help them adapt to the innovative environment.

The cement industry remains committed to providing growth and jobs in Europe. We are eager to engage with policymakers to ensure that an ambitious, yet realistic, legal framework is developed – one which incentivises CO₂ emission reduction and energy efficiency improvements, and which provides sufficient room for investments that will allow Europe to maintain its leading role.

The Role of Cement in the 2050 Low Carbon Economy

Five Parallel Routes: This 2050 roadmap is based on 5 parallel routes that can each contribute to lowering emissions related to cement production, as well as concrete production. The first 3 routes are quantified in this roadmap. The final ‘product efficiency’ and ‘downstream’ routes look at how cement and concrete can contribute to a low carbon society, providing a connection from this roadmap to the construction sector.

http://lowcarboneconomy.cembureau.eu/
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- Concrete innovation

Other relevant projects

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- Concrete innovation

REDMUD
- Innovative binder
What is CEMCAP?

CEMCAP is a project funded by Horizon 2020 addressing CO₂ capture from cement production. The primary objective of CEMCAP is to prepare the ground for large-scale implementation of CO₂ capture in the European cement industry. CEMCAP will demonstrate CO₂ capture technologies for the cement industry in an industrially relevant environment. Existing pilot-scale test rigs, adapted to replicate realistic cement plant operating conditions, will mainly be employed, and in addition a dedicated clinker cooler for oxyfuel cement plants will be designed and built. Cost and energy efficient retrofit of the capture technologies will be targeted, with focus on maintained product quality.

More information: [http://www.sintef.no/cemcap/](http://www.sintef.no/cemcap/)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641185.

Who are the partners?

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CEMCAP objectives

The European cement industry has committed itself to contributing to climate protection measures and therefore to curbing its CO₂ emissions. CO₂ capture technologies, although an essential part of all CO₂ reduction scenarios, are not yet ready for large-scale deployment in the cement industry. Hence, the primary objective of CEMCAP is to prepare the ground for large-scale implementation of CO₂ capture in the European cement industry. To achieve this objective, CEMCAP will

- Leverage to TRL 6 for cement plants the oxyfuel capture technology and three fundamentally different post combustion capture technologies, all of them with a targeted capture rate of 90%.
- Identify the CO₂ capture technologies with the greatest potential to be retrofitted to existing cement plants in a cost and resource effective manner, maintaining product quality and environmental compatibility.
- Formulate a techno-economic decision-basis for CO₂ capture implementation in the cement industry, where the current uncertainty regarding CO₂ capture cost is reduced by at least 50%.

For successful large-scale deployment of CO₂ capture in the cement industry, technologies must be developed beyond the current state of the art. In order to bring the most promising retrofittable CO₂ capture technologies to a higher TRL level and closer to implementation, CEMCAP will

- Describe the routes for the development required to close technology gaps for CO₂ capture from cement and assist technology suppliers along the related innovation chains.
- Identify and follow up minimum five potential innovations springing from CEMCAP research.

Technologies suitable for CO₂ capture retrofit are focused on in CEMCAP, because cement plants typically have a lifetime of as long as 30-50 years, and very few new plants are being built. However, the results from CEMCAP will enable looking beyond the horizon for implementation of CO₂ capture in existing cement plants. New plants and novel CO₂ capture integrations based on CEMCAP results can be envisaged. Therefore, CEMCAP will create pathways for the low to near-zero CO₂ emission cement production of the future.
**Project contents**

The CEMCAP project consists of twelve work packages (WP) that are grouped in four sub-projects (SP):

- Project management, dissemination and exploitation (WP1, WP2) - SP1
- Framework and comparative analysis (WP3, WP4, WP5) - SP2
- Oxyfuel capture retrofit (WP6, WP7, WP8, WP9) - SP3
- Post combustion capture retrofit (WP10, WP11, WP12) - SP4

The overall methodology of CEMCAP is to iterate between experimental work in pilot-scale test rigs and simulations of capture technology integration and cost analysis, to assess the impact of CO2 capture on the cement production process. Technology development and demonstrations in simulated industrial environments (gas compositions and other conditions adapted to replicate the operating conditions of a cement plant) will be conducted during 36 months in SP3 and SP4 (until April 2018). In order to provide sufficient time for analysis and dissemination of results after the experimental work is concluded, SP1 and SP2 will continue until month 42 (October 2018).

**Progress beyond state of the art**

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far). All the experimental research in CEMCAP is progressing CO2 capture from cement plants beyond state of the art, towards results we will be possible to say that the CEMCAP technologies have been demonstrated in an industrially relevant environment (TRL6). The oxyfuel pilot-scale clinker cooler is unprecedented in its innovative design, just as the oxyfuel burner adaptations and the new oxyfuel nozzle design are unprecedented. Calcination is tested in a CO2 rich-environment relevant for oxyfuel, and calcium looping tests with a high substitution rate of CO2 absorber has not been tested before. A chilled ammonia absorber has never before been tested for such high CO2 concentrations (up till 35%).

Furthermore, the CEMCAP Framework provides an unprecedented assembly of knowledge and data for simulations of CO2 capture from cement plants. This includes how to take into account the varying false air ingress, which leads to varying exhaust gas flowrates and CO2 concentrations, even for a cement plant operating at steady state. When made public in 2017, and thoroughly promoted by CEMCAP, the framework will provide background for other projects to undertake CO2 capture studies that can deliver results comparable to CEMCAP results. Knowledge sharing is essential for the progress and impact of CEMCAP. Industrial and research partners with backgrounds in cement and in CO2 capture from power plants have met during the first CEMCAP/ECRA workshop, the project-internal technical meetings and also interact continuously through the ongoing research. Altogether, the CEMCAP project is progressing towards identifying the most cost- and resource effective options for CCS in the cement industry, and hence in a longer perspective towards expanding the options for CCS deployment in Europe.
ECO-BINDER

Development of insulating concrete systems based on novel low CO2 binders for a new family of eco-innovative durable and standardised energy efficient building envelope components

Objective

The main objective of the project is to demonstrate the feasibility of replacing Ordinary Portland Cement (OPC) and OPC based concrete (products) with new products based on the innovative Belite-Ye’elimite-Ferrite (BYF) class of low-CO2 binders. ECO-Binder aims to address the vast market for envelope retrofitting and new construction with a new generation of prefabricated building envelope components with

- 30% carbon footprints decreased
- 20% insulating properties improved
- 15% cost reduced relative to current solutions based on Portland cement.

In order to be cost-effective and sustainable in a highly-competitive market, the new building envelope solutions will integrate even more functions in a single product package.

Prefabricated concrete systems of different complexity (from ordinary blocks to sophisticated insulated wall panels) and end-use will be installed in different climatic conditions for demonstration purposes. Their environmental performance will be validated through dedicated LCAs.

Pre-cast products developed in this project are intended for new construction as well as for deep retrofitting, as for example the renovation of commercial buildings or social housing construction. The approach taken within the ECO-Binder project will lead to the development of a novel family of cement binders. This will enable the construction materials sector to progress towards commercializing eco-sustainable products with comparable performance to traditional products.

The overall concept of the project builds on previous work by HeidelbergCement, Lafarge and Vicat to develop a novel family of low CO2 binders based on Belite, Ye’elimite and Ferrite phases (BYF cements). In BYF technology, the superior early age strength contribution of calcium-sulfo-aluminates (CSA) is combined with durability provided by belite.

The raw materials and the production process for BYF cements, are similar to those of Portland cement (OPC), but the CO2 emissions are about 30% lower as shown in preliminary LCA calculations. This is due to the lower calcium content of the raw materials (less limestone usage) the lower clinker burning temperature of around 1250-1300°C and the lower grinding energy demand. These same factors also result in a significantly lower embodied energy than OPC. Combining these novel binders with insulating materials and advanced functional finishing methods will permit the development of novel concrete systems with low CO2 and low embodied energy suited for a wide range of envelope components, without compromising technical, health and environmental standards. The new systems will result in an
improved construction process with reduced time and costs. The ECO-Binder project follows a holistic approach: Material science research on BYF cement and concrete and on advanced finishing materials like mortars, plasters, paints or coatings, will lead to the development of concrete elements with reduced embodied energy, improved insulation properties and providing multifunctional surface properties like thermal reflection, antibacterial, anti-stain, self-cleaning.

Fully optimized sustainable envelopes will show at least 20% better insulating performance than currently available solutions, and ensure durability and the necessary mutual compatibility between the different components. Improved acoustic performance, as well better health and safety will be also provided at sustainable installation costs. Given the expected life span of fifty or more years, it is important not only that the new envelope systems be energy efficient and eco-friendly, but that they also behave similarly to traditional solutions. This means that concrete based on the new low-CO₂ BYF cements needs to be durable and be capable of being placed or cast easily.

http://www.ecobinder-project.eu

This project is supported by the European Commission under the Energy Theme of the Horizon 2020 for research and Technological development. Grant Agreement number 637138
The cement industry’s approach to carbon capture

**ECRA’s approach from basic research towards an industrial implementation of carbon capture**

- All low-carbon roadmaps require a significant reduction of CO₂, also in the cement sector.
- Correspondingly and according to CEMBUREAU approx. 60% of cement plants in the EU should be equipped with CCS technology by 2050.
- Based on the need to develop this breakthrough technology, ECRA is investigating its technical and economic feasibility in its CCS research project.
- A focus is also being placed on CO₂ reuse in cooperation with the University of Mons.
- In the current phase IV of the project an oxyfuel pilot plant is being prepared, taking economic and technical issues into account.

**Post-Combustion and oxyfuel technology as potential capture solutions for the cement industry**

**Post-Combustion:** Tail-end separation of CO₂ from flue gas by e.g. chemical absorption, adsorption, membranes or Ca-looping.
- A very energy-intensive technology.
- Important projects: Norcem’s Brevik project (pilot testing), CEMCAP (prototype testing).

**Oxyfuel Technology:** Combustion with pure oxygen instead of air in combination with flue gas recirculation to increase the CO₂ concentration.
- Requires process and design adaptations.
- Important projects: ECRA (complete oxyfuel), LafargeHolcim/Arilique/FLSmidth (pilot testing of partial oxyfuel), CEMCAP (prototype testing).

**Envisaged next steps towards an industrial-scale oxyfuel cement kiln**

- Demonstration of technical and economic feasibility in an industrial surrounding.
- Designs: Brownfield (new installation using the infrastructure of existing line) or blackfield (retrofitting existing line).
- Size: Industrial-scale > 500 t/d
- Two potential locations are currently being evaluated.
- Projects costs estimated at up to 90 M €.
- Project includes engineering/construction, training and operation/scientific evaluation.
- Project requires significant funding.
- Time horizon: Starting the project in 2017, the plant could be operated in 2019/2020.

**About ECRA and the European cement industry**

- The cement industry in Europe: a highly innovative sector, underlined by the establishment of ECRA in 2003.
- Members of ECRA: 47 cement manufacturers, associations and technology providers from mainly European but also non-European countries.
- Internationally recognised European research body in cement and concrete technology.
- Collaboration in R&D of technology providers and cement manufacturers to bring innovative products and improved manufacture processes to the market.
- Interrelations with associations to communicate the cement industry’s activities.
The LEILAC project (Low Emissions Intensity Lime And Cement) will successfully pilot a breakthrough technology that aims to replace an existing part of the cement and lime making process, and enable the capture of unavoidable process carbon dioxide (CO$_2$) emissions without significant energy or capital penalty.

A unique consortium of partners – from leading industrial, modelling, academic and engineering organisations - has come together to create this ground-breaking carbon capture pilot project.

This five year project has been funded by the consortium members (€9M) and the European Commission through the Horizon 2020 research and innovation programme (€12M, grant no. 654465).

Company website: [www.project-leilac.eu](http://www.project-leilac.eu)

Technologies for carbon emission valorisation

Technology development

LEILAC will develop, build, operate and test a 240 tonne per day pilot plant at HeidelbergCement’s plant in Lixhe, Belgium, demonstrating that over 95% of the process CO$_2$ emissions could be captured (60% of a plant’s total CO$_2$ emissions). The LEILAC pilot should become operational in 2019, and will trial the technology under actual operating conditions, with a variety of tests; facilitating the technology to be scaled and applied to full scale cement and lime plants as quickly as possible. This technology will allow both the cement and lime industries to capture their process CO$_2$ emissions for no energy penalty (just compression) and at comparable capital costs to conventional emitting equipment – enabling the low cost valorisation of inherent carbon emissions.
Figure 1 shows the overall concept of the LEILAC project, which focuses on the development of Calix’s Direct Separation (DS) technology. This simply re-engineers the existing process flows of a traditional calciner, by indirectly heating the material being processed via a special steel vessel. This unique system enables pure CO₂ to be captured, in the case of limestone, as it is released during calcination.

**Potential impact**

This innovation requires minimal changes to the conventional processes for cement manufacture, and simply replaces the calciner. The solids will then pass into the kiln as they would in a typical cement plant. In a lime plant, the unit will just replace the kiln.

This elegant solution requires no additional chemicals or processes – resulting in no contamination of the CO₂ released by the processed materials, nor additional environmental emissions. The pilot will assess the quality of the separated process CO₂. It is expected that this design will allow the cement and lime industries to quickly, cheaply and efficiently valorise high quality CO₂ that would have been otherwise emitted. It can also work in conjunction with other carbon capture techniques to address the remaining heating emissions.

As well as demonstrating that the technology works as expected at this scale, there will be a techno-economic analysis, and a Life Cycle Analysis of the technology as it would be applied at full scale. This will result in a Roadmap for the technology’s scale up and deployment. The project’s results will be shared widely through ongoing publications, conferences, website, and the visitors centre at the pilot site near Brussels.

**Key words**

Cement, lime, Carbon capture, CO₂, carbon dioxide, low emissions, Direct Separation, LEILAC.

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Concrete is the ideal material to meet many of the challenges the world will face in the coming decades: it is low-carbon made from abundant resources, capable of integrating large quantities of waste and by-products and is extremely durable.

Using alternative construction materials would, in many cases, not be a sustainable solution. Forest growth would not be able to compensate a dramatic increase in the use of wood and increasing steel production for construction would lead to higher emissions. Furthermore, concrete is the only viable material for many applications such as foundations, high rise structures, or dams.

Nevertheless we should explore all possible options to reduce the emissions linked to cement and concrete production and save resources.

Emissions in cement production are threefold:
- From the production of the electrical energy used to grind the raw materials and clinker;
- From the fuel burned to heat the raw materials in a kiln to 1450°C to form clinker, which is later crushed and blended with gypsum to make cement;
- Process emissions: as the limestone is heated, it changes into lime and CO₂. These emissions represent 60 to 65% of total emissions linked to cement production.

Since process emissions, caused by the use of limestone, are responsible for most of the emissions, it would make sense to think that we simply have to use another raw material. However, there is a catch. Limestone is widely available close to almost all places where cement is used, and no viable substitute has yet been found despite many decades of intense research. It is possible to envisage niche products using alternative materials, but the bulk cement will still be Portland cement using limestone as a main raw material.

This is why our research does not focus on finding a revolutionary type of new cement, but rather on making concrete even better.

We study cement and concrete at a microscopic level to help understand the scope of physical and chemical reactions that occur when using different cement types or materials in the concrete mix. Furthermore, we look at how the concrete is likely to perform in the future.

Fundamental research is needed to study these complex materials and their interaction with the environment that surrounds them.

Using advanced techniques like atomic force microscopy, X-ray diffraction and transmission electron microscopy we get a better understanding on what goes on inside concrete. Gaining this knowledge will help develop solutions that will lower the carbon impact of concrete.
Our research supports several parallel pathways of reducing concrete's carbon impact:

■ Improved prediction of performance of new types of cement and concrete. Because safety comes first, there has been a tendency to use a concrete that is stronger than actually needed. Increasing our understanding of how each concrete will perform for the next 50 to 100 years will increase the use of cement and concrete types with lower emissions per tonne.

■ Research into the performance of different mixtures could lead to concrete types that use less cement whilst ensuring equal structural integrity over time.

■ Increase understanding how concrete deteriorates and ensure new materials will be durable.

■ In Europe, more than 20% of clinker is replaced by waste materials or industrial by-products like blast furnace slag or fly ash. Decreasing the amount of clinker reduces both process emissions (originating from the decomposition of limestone) and thermal emissions. Our research looks into the performance that different cement types with alternative materials have today and might have over time.

■ Our research actively explores possibilities for new replacement materials such as calcinated clays or pozzolans or optimising the use of the replacement materials used today.

■ We investigate the impact of chemical admixtures on concrete performance. Admixtures can help improve the properties of concrete, making it more durable and sustainable.
Current development status of the Celitement system
Celitement pilot plant

At last year's 55th BetonTage congress, the concept, production and properties of this completely new binder were presented. Back then, only small amounts of the material (in the kilogram range) could be produced on a laboratory-scale installation at KIT. For this reason, plans were proposed to commission a pilot plant enabling an output of at least 100 kg per day that should also provide the design parameters for a first industrial reference plant to be set up by the Celitement shareholder, Schwenk Zement.

The pilot plant was officially commissioned on 11 October 2011 (Fig. 1), and has been in operation ever since. This installation provides a high degree of flexibility with respect to the testing of a broad range of possible input materials for manufacturing Celitement products because the Celitement system is not just a single product but encompasses an entire range of innovative binders. Whereas the dry process appears to be the only viable option for large-scale industrial production (with the intermediate autoclaved products not requiring any additional drying step), the completed pilot plant is also capable of implementing a so-called wet process that involves a downstream drying stage in a heated membrane filter press.

Today, the pilot plant is successfully producing autoclaved material applying the dry process in a fully automated manner, delivering an output of up to 150 kg per batch.

A great variety of test installations is currently being used for the second step involved in the manufacture of Celitements, which requires the tribochemical activation using various silicate carriers in order to arrive at the finished product. The products manufactured in this process are undergoing a wide range of basic tests regarding the underlying mortar and concrete technology. However, the large number of post-


Mit der offiziellen Einweihung am 11. Oktober 2011 (Abb. 1) hat die Pilotanlage mittlerweile ihren Betrieb aufgenommen. Da das Celitement-System nicht ein einziges Produkt, sondern eine ganze Familie neuer Bindemittel darstellt, bietet die Anlage eine große Flexibilität bezüglich des Tests der unterschiedlichsten Rohstoffgrundlagen, die zur Herstellung von Celitementen möglich sind. Während eine großindustrielle Herstellung nur im sogenannten Trockenverfahren sinnvoll erscheint, d. h. die Zwischenprodukte aus dem Autoklaven keinen weiteren Trocknungsschritt mehr benötigen, ist die jetzt fertiggestellte Pilotanlage auch in der Lage, ein sogenanntes Nassverfahren mit anschließender Trocknungsstufe in einer beheizbaren Membranfilterpresse abzubilden.

Die Herstellung von Autoklavenmaterial nach dem Trockenverfahren gelingt in der Pilotanlage mittlerweile vollautomatisch und liefert Produktionschargen von bis zu 150 kg pro Ansatz.

Die im zweiten Produktionsabschnitt von Celitementen notwendige tribochemische Aktivierung mit unterschiedlichen Silikaträgern zum eigentlichen Endprodukt erfolgt derzeit noch mit unterschiedlichsten Testanlagen. Die dabei hergestellten Produkte werden den verschiedensten Mörtel- und betontechnologischen Grundlagenuntersuchungen unterzogen. Die Vielzahl der möglichen Celitementtypen, mit teilweise stark auf einzelne Applikations-

Building of the pilot plant in Karlsruhe
Gebäude der Pilotanlage in Karlsruhe
sible types of Cemitelement, whose properties can be optimized for specific areas of application, necessitated a selection and restriction to only a few intermediate and finished products, which is why the first greater production batches were restricted to a simple Cemitelement variant that was not adjusted to maximize its performance for a specific application. As far as reasonably possible, this product manufactured in larger volumes was to serve as a representative sample of the general composition and working principle of Cemitelements.

These initial pilot samples (Fig. 2) are currently being used to carry out, for the first time, large-scale tests and analyses of the characteristics known from the mortar tests previously performed on a laboratory scale. This also includes testing of the interactions with commercially available plasticizers because the water/binder ratios are generally lower in the Cemitelement system, which is why the application of plasticizers appears useful to better control the setting processes. The larger product volumes are now also being used to clarify some other fundamental issues, such as the carbonation characteristics of concretes produced with Cemitelement.

It is also possible to systematically test the very wide range of optimal particle size distributions for the first time, which were not thoroughly investigated in the previous laboratory tests.

The finished products showed a very bright white shade otherwise only known from industrially produced white cement because the initial pilot plant trial runs were carried out using very pure raw materials. Although Cemitelements will probably first be used for special construction materials such as tile adhesives, fillers, plasters or mortars for which product color is an interesting feature, the development of Cemitelement was initially not geared towards optimizing the color fidelity of the material. However, this example demonstrates the additional options that the new system can provide, as well as the possible value added for its users. Another big issue currently being investigated and requiring a major investment relates to the approval of Cemitelement under applicable chemicals regulations as part of a REACH authorization process. Since the risk assessment concept under European chemicals legislation is linked to the potential annual production output, a new construction material such as Cemitelement is automatically allocated to the highest risk category and to the associated, extremely sophisticated testing schemes. Outside a research project officially notified to the European Chemicals Agency (ECHA), however, neither the transport nor the sale of Cemitelement to non-registered users is possible without a completed registration procedure under applicable chemicals legislation, which is another reason why no material samples have yet been made available to parties other than the project partners.


Auch der sehr große Bereich optimaler Kornverteilungen, der in den vorangegangenen Laborversuchen nicht näher untersucht wurde, kann nun erstmals systematisch abgeprüft werden.

CEMEX
CEMEX one of the leading global players in the cement industry, and is highly engaged in mitigating climate impacts, by increasing the energy-efficiency, the use of alternative fuels and reducing the clinker content in cement. CEMEX has reduced the net CO₂-emissions per ton of cementitious material in 2015 by approx. 22% compared to 1990. As founding member of the Cement Sustainability Initiative (CSI, part of WBCSD) a CSI Roadmap has been developed which emphasizes the importance of applying carbon capture and storage or utilization to further reduce the CO₂ footprint of the industry.
www.cemex.com

Technologies for carbon emission reduction
Technologies for CCUS are at different stages of maturity and with a wide variety of potential applicability and hurdles to overcome. CEMEX therefor addresses the topic at different levels. The strategy is not to have quick-wins, instead to address the topic systematically from different angels and to develop the larger scale potentials in collaboration with technology developers and downstream value chain partners.

CO₂ for algae cultivation (Alicante Spain)
CEMEX did several tests in algae demonstration farms. The latest and most successful project is currently performed in our plant in Alicante, Spain. There we supply land for the algae plant, CO₂ from our kiln’s exhaust gases, water and electricity. The algae demonstration plant is managed by another company, which supplies such plants in a small commercial scale. With this demonstration plant, we test their new technology, assist in developing it further and do tests for different product streams like biofuels, pigments and omega-3. These routes are tested to provide the best economics before scale-up. The TRL of this demonstration is between 6 and 7, but a scale up to commercial scale is possible, with our partner.

CO₂ Capture by Calcium Looping
CEMEX has developed together with several other partners in the two EU projects Cal-Pilot and SCARLET the Calcium Carbonate Looping (CCL) Technology to a large scale demonstrator unit. The running SCARLET project is currently performing long-term tests using an upgraded 1 MWth pilot plant, aiming mainly at optimization of operating conditions and operational reliability. The successful operation of the upgraded pilot will provide the important validation step between the 1 MWth scale and a future 20 MWth scale pilot. The project will provide a techno-economic as well as an environmental assessment of this high-potential technology for CO₂ capture from power, cement and steel production plants, and provide the fundamental expertise needed for the scale-up and further technology development and integration.
**CO₂ Capture by Redesigning of Calciner**

CEMEX and Heidelberg are partners in the EU project LEILAC (Low Emissions Intensity Lime And Cement). The project is aiming on to construct a large pilot (200 t/day) Direct Separation production plant as a breakthrough technology. The technology has the potential to enable both Europe’s cement and lime industries to reduce their emissions dramatically while retaining, or even increasing international competitiveness. The breakthrough calciner can directly separate and capture the CO₂ released from limestone when being transformed into clinker. Since over 60% of our CO₂ emissions originate from the calcination of limestone, and we could separate this CO₂ without using more energy, this brings carbon capture much closer to financially feasibility.

**CO₂ Avoidance by Industrial Symbiosis**

CEMEX is one of the 5 global process industry partners that are part of the EU project EPOS (Enhanced energy and resource Efficiency and Performance in process industry Operations via onsite and cross-sectorial Symbiosis). The 5 partner represent not only 5 key relevant sectors: steel, cement, chemicals, minerals and engineering, but have together as well about 500 000 employees, represent 166 bn € in sales and have 75% of their production located in Europe. EPOS's main objective is to enable cross-sectorial Industrial Symbiosis (IS) and provide a wide range of technological and organizational options for making business and operations more (resource and energy) efficient, more cost-effective, more competitive and more sustainable across process sectors. The cross-sectorial IS is tested in 5 clusters strategically located throughout EU.

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CONTINUOUS REDUCTION IN CARBON EMISSIONS DUE TO:
• ongoing investment
• further fossil fuel replacement
• increasing clinker substitution

CARBON––––––––
EACH BAG HAS A 20% LOWER CARBON FOOTPRINT

CONTINUOUS REDUCTION IN CARBON EMISSIONS DUE TO:
• ongoing investment
• further fossil fuel replacement
• increasing clinker substitution

MODERN DRY PRODUCTION FACILITIES
4 cement kilns on the Island using BAT dry process clinker manufacturing. Energy efficient mills require 30% less electricity putting Ireland ahead of the EU average

€500 MILLION INVESTED IN MODERN PLANT SINCE 2000

MODERN DRY PRODUCTION FACILITIES
4 cement kilns on the Island using BAT dry process clinker manufacturing. Energy efficient mills require 30% less electricity putting Ireland ahead of the EU average

INVESTMENT

2,000 PEOPLE EMPLOYED

JOBS

40% EXPORTED TO THE UK AND EUROPE

MARKETS

2,000 PEOPLE EMPLOYED

Chemical, mechanical, electrical, process and environmental engineers are essential to operate cement manufacturing facilities

FUELS

>34% OF THE FOSSIL FUELS HAVE BEEN REPLACED

FOSSIL FUEL REPLACEMENT
Since 2008 there has been steady progress replacing imported fossil fuels with ‘ready-to-use’ fuels produced from local residual waste materials. Long-term target is >85%

ALTERNATIVE FUELS

1 TONNE OF CO₂ SAVED FOR EVERY TONNE OF SRF OR TYRES USED TO REPLACE FOSSIL FUELS

ALTERNATIVE FUELS

Source: Prognos Report, 2008
Resource savings and CO₂ reduction potential in waste management in Europe and the possible contribution to the CO₂ reduction target in 2020

MARKETS

DOMESTIC AND EXPORT MARKETS
Through cost efficient operations and flexible work practices the industry has secured and grown these vital export markets

ALTERNATIVE FUELS

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Source: Prognos Report, 2008
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Source: Prognos Report, 2008
Resource savings and CO₂ reduction potential in waste management in Europe and the possible contribution to the CO₂ reduction target in 2020

ALTERNATIVE FUELS
Cement Production in Ireland 2016

CEMENT PRODUCTION

RAW MATERIAL PREPARATION
- Quarry – local materials
- Limestone = 80%
- Milling to a fine powder
- Quality control

CLINKER PRODUCTION
- High temperature >1450°C
- Fuel combustion in the kiln
- Fossil fuel replacement
- Quality control

CEMENT MILLING
- Energy efficient mills
- 2 main cement types
- Clinker replacement
- Quality control

PRODUCTS

ECO-EFFICIENT CEM II CEMENTS
Since 2006, Eco-efficient CEM II cements have been manufactured using local raw materials and now represent more than 80% of cement sales in Ireland.

CERTIFICATION

Independent International Verification
ISO 9001 – Quality
ISO 14000 – Environmental
BES 6001 – Responsible Sourcing

CONCRETE

STRONG, SAFE, SUSTAINABLE
Concrete – 2nd most used substance on the planet after water

Circular Economy
- Local materials
- Durable, resilient
- 100% recyclable

Comfortable, affordable housing
- Thermal mass
- Fire resistance
- Security
HeidelbergCement

As one of the leading global players in the cement industry, HeidelbergCement is highly engaged in mitigating climate impacts. By increasing the energy-efficiency, the use of biomass fuels and replacing clinker in cement, HC has reduced the net CO₂-emissions per ton of cement in 2015 by 23% compared to 1990. As founding member of the Cement Sustainability Initiative (CSI, part of WBCSD) a CSI Roadmap has been developed which emphasizes the importance of applying carbon capture and storage or utilization to further reduce the CO₂ footprint of the industry.

Heidelberg Cement is also founding member of the European Cement Research Academy (ECRA) and has invested together with ECRA in carbon capture and storage (CCS) technologies. As we consider Carbon Capture and Utilization (CCU) applications complementary to CCS, we are monitoring this sector for transformative solutions to the climate problem.

www.heidelbergcement.com

Technologies for carbon emission valorisation

HeidelbergCement is set to become a founding member of an European CCU-association, to jointly address the barriers to the regulators within the EU and its member states. Technologies for CCU are at different stages of maturity and with a wide variety of potential applicability and hurdles to overcome. HeidelbergCement’s strategy is to implement quick-wins, even when they are now small in terms of CO₂-abatement, and to systematically develop the larger scale potentials in collaboration with technology developers and downstream value chain partners.

CO₂ for algae cultivation

After finalizing our R&D-programs in Degerhamn-Sweden, Canakkale-Turkey and Gargenville-France, we consider the growth of micro-algae using fluegas from cementkilns without purification, and generating dry biomass for animal feed, as TRL 6.

In next steps we are initiating CCU-micro-algae demonstration programs to reach TRL7 to TRL8, where we will generate sufficient dry micro-algae to test animal feed applications in the market. Programs are developed with technology partners as well as a company with its core business in animal feed. In order to reach TRL9 a number of hurdles are to be taken:

- prove the stability and added value of animal feed based on micro-algae grown with fluegas
- intensify the collaboration with partners in the whole value-chain
- secure that regulation allows to supply animal feed based on this technology
- attract funding / co-investors in the stage from TRL 6 to TRL 8

The market is large enough to allow for large scale algae-farms capable of re-using upto 10% of the CO₂ emission of a mid-sized European cement kiln. Availability of (salty) water, enough solar intensity and reasonable flat (non-arable) land is required. Sea-borne algae-growth is another domain of attention. Combination with waste water treatment (a nutrition source for the algae) would deliver further ecological and economical optimizations.
**CO₂ to methane or other transport fuels**

In order to connect to a large market, the generation of methane suitable as low-carbon fuel for the transport sector is another strategic development of HC to valorize CO₂. Hydrogen (H₂) required for those technologies will be generated by renewable energy. In case this is done in oversupply situations, it serves as a power-to-gas approach.

The power-to-gas concept of methanation has been proven based on a CO₂-stream from a biogas plant in Germany (TRL 8). However the use of flue-gas from industrial processes such as cement kilns as source for “Power-to-Gas” is new. The main challenges are:

- technical: concentration of the CO₂-content of the flue gas and prepare the flue-gas in relation to the methanation technology applied, as well as scale up of the technology
- regulatory: synthetic biofuels are not yet recognized in the German regulatory framework as biofuels which means that premiums related to the use of biofuels are unsure for investors

HeidelbergCement assessed the potential of these “Power-to-gas”-facilities located on cement sites on recovery of a substantial 2 digit % level of the total CO₂-emissions of the German cement industry.

**CO₂ carbonation**

CCU-technologies fitting best to the cement and aggregate industry are those that use CO₂ from flue gas to carbonate (waste) minerals into building materials. These processes use exhaust gases to carbonate for example olivine or other products that consist of a considerable amount of free lime, such as incineration ashes or oil shale ashes. Such technologies are different from classical capture technologies, as they bind the CO₂ in a long lasting construction material that has an improved environmental footprint compared to classical binder materials.

Factors that determine the success of CO₂-carbonation applications are on the one hand the costs and availability of (waste) minerals and the market size and -value of the generated materials. The amount of CO₂ uptake per ton of end-product is another decisive factor for the attractiveness of the technology.

**Key words**

Mineralization, carbonation, micro-algae, alternative sustainable fuels for transport, renewable energy storage, cement kiln flue gas, CCU

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PROJECT AETHER: REDUCING THE INTRINSIC CO₂ EMISSIONS FROM CEMENT PRODUCTION

Project

Project Aether aims to develop a new, innovative class of clinkers with a lower environmental footprint. Clinker is the main component used to produce cement, through grinding and mixing it with additions like sulphates, and cementitious materials such as fly ash, slag or other pozzolanic materials. Less limestone is required to produce Aether® cements, which are also manufactured at lower temperatures and using less energy than conventional Portland cement. This allows a 25-30% reduction in CO₂ emissions during the production process. Aether® clinkers can be made from conventional raw materials that are suitable for use in large scale cement manufacture: limestone, clay, iron and bauxite. They can also be produced in existing industrial installations - 'rotary kilns' - after certain process adaptations have been made. Aether® cements are expected to offer similar performances to conventional Portland cement in various concrete applications.

Project Aether is run by LafargeHolcim, a world leader in building materials, working in partnership with BRE, the UK’s leading centre of expertise on building and construction, and the institute of Ceramics and Building Materials (ICMB), the Polish research institute, which provides engineering and consulting support to the lime and cement industry, authorities and end-users. The project is supported by the European Community through the LiFe+ financial instrument with up to 2.3 M€, out of a total budget of 5.9 M€. This 3 year project ran from 1 September 2010 to 31 August 2013. For further information:

http://www.aether-cement.eu/about-project-aether.html

Aether clinkers and cements were also used in two additional European funded projects with the goal to develop and test new sustainable low CO₂ end user solutions.

- “Development of cost-effective industrialization of AETHER lower-carbon clinker” with contribution of the European Union’s LIFE financial instrument for the environment and Sustainable Industry Low Carbon (SILC) scheme from December 2013 to May 2015 (overall budget 1.25 M€)
- “Development of insulating concrete systems based on novel CO₂ binders for a new family of eco-innovative, durable and standardized energy efficient envelope components” in the Energy scheme of the H2020 program from January 2015 to December 2018 (7.6 M€), a joint R&D effort of 3 cement producers (LafargeHolcim, Vicat and Heidelberg Cement) with 12 other partners. Further information is available on http://www.ecobinder-project.eu/

Industrial trials

Lafarge has successfully completed two industrial trials for Aether®, its new generation clinker formulated for lower carbon cements. These trials have confirmed the feasibility of industrial-scale production of Aether® cements, in existing installations and using traditional raw materials, for a lower overall environmental footprint. Thanks to support from the EU’s LIFE+ environmental funding program, Lafarge has carried out trials at two of its French cement plants, the first in February 2011 and the second in December 2012. Following pilot tests at ICMB facilities in Poland, these two industrial trials confirmed that Aether® clinkers for cement can be produced in kilns designed for Portland cement clinker production and using similar process parameters and fuels. Conventional raw materials can be used; it is simply the proportion of each that changes in comparison to Ordinary Portland Cement (OPC). The trials were also very encouraging in terms of environmental performance, confirming that Aether® clinkers can be produced at lower temperatures (1225 -1300°C) than Portland cement clinkers (1400-1500°C) and using significantly lower energy (~15%). Furthermore, Aether® cement grinding requires lower energy than OPC. Overall, this means that the expected objective of a 25-30% reduction in CO₂ emissions per ton of cement was met.

Interesting lessons on industrial process

While Aether® clinker production is similar to Portland clinker production, the industrial trials showed that a higher level of control is needed for each process step. In particular, a very narrow temperature range is required in the clinkering zone of the kiln, to ensure that the clinker is burned in an optimum manner with controlled gas emissions. Too high a temperature in the clinkering zone also leads to a risk of ring formation
or melting that can force a kiln stop and the over burnt clinker is harder to grind. Nitrogen oxide (NO\textsubscript{x}) emissions are lower than with OPC production, due to the lower temperature at which Aether® clinkers are produced. If the raw mix is correctly designed and the clinkering temperature well monitored, Aether® clinker production generates the same level of SO\textsubscript{x} emissions as OPC.

### Testing programme

Testing is being carried out by Lafarge research teams and UK-based BRE to assess the mechanical properties and durability of mortars and concretes made with Aether® cements. So far, results have been encouraging: concretes made with Aether® cements show higher early strength gain and lower shrinkage than concretes made with Ordinary Portland Cement (OPC).

### Reactivity and strength of Aether® cements

Concretes produced with Aether® cements show high early compressive strength gain of around 20MPa at 6 hours and compressive strength at 28 days equivalent to that achieved with a standard cement (CEM I 52,5R). Furthermore, Aether® cements show better dimensional stability than OPC: testing has demonstrated 50% less shrinkage of concretes made with Aether® cements compared to concretes made with OPC.

### Durability testing program

Durability testing is an important part of the project, with Aether® cements tested for their resistance to a number of well-identified risks, in particular the risk of corrosion of the steel rebars used in structural concretes and the risk of degradation of the concrete itself. The very nature of durability testing means that it takes time to obtain conclusive results, although accelerated laboratory tests allow extrapolation to predict how a material will react to specific conditions in the future.

Different concrete mix designs have been developed for durability testing, representing a variety of different concrete applications:

- Mix design 1: typical C20/25 concrete for use without steel reinforcements in non-structural applications.
- Mix design 2: typical C25/30 concrete for use with embedded steel rebars in structural applications such as slabs, walls and columns, in non-aggressive environments.
- Mix design 3: typical C35/45 concrete for use with embedded steel rebars in structural applications in chemically aggressive environments (presence of acid in soils, seawater chloride or industrial applications).

The durability program includes the following tests:

- **Carbonation ingress**
  
  BRE is measuring the oxygen permeability (‘durability index’) of the three concrete mix designs compared to Portland-based concrete and their resistance to atmospheric carbonation, which reduces the pH of concrete and leads to a risk of corrosion of the embedded steel bars. BRE is running both accelerated laboratory tests and natural outdoor tests.

- **Chloride ingress**
  
  There is a risk of corrosion of the embedded steel rebars if the surrounding concrete is exposed to seawater or de-icing salt or is used for structures in a maritime environment. The ‘chloride diffusion coefficient’ is being measured for concrete mixes n°2 and 3, which are more likely to be used in these conditions.

- **Resistance to chemically aggressive attacks such as sulfate and organic acid**
  
  This is particularly important for concretes used in aggressive soils or industrial applications. Experiments are being run to determine the stability of Aether®-based samples in this type of aggressive medium, specifically concrete mixes n°2 and 3.

### Developing Aether® cements for specific applications

LafargeHolcim is now looking at a wide range of potential applications for Aether cements, for example in the precast segment, where their high early-strength gain could be a particular advantage over classical OPC cements. Other sectors include building applications (screed; insulating walls) and infrastructure (seawater resistant concretes; repair mortars for roads).
LafargeHolcim:

Founded in 2015 following the merger of Lafarge and Holcim, LafargeHolcim operates in 90 countries. LafargeHolcim solutions and services include cement, concrete, and aggregate solutions for the following businesses: buildings, infrastructure, distribution, oil and gas, affordable housing, and construction systems. With 386.5 mt of installed capacity worldwide, more than 2,500 plants (including over 1,600 in ready mix concrete, over 600 in aggregates, over 180 in cement, and 70 grinding plants) and 115,000 employees, LafargeHolcim is a worldwide leader (www.lafargeholcim.com).

Solidia Technologies:

Solidia Technologies is a cement and concrete technology company that makes it easy and profitable to use CO₂ to create superior and sustainable building materials. Solidia’s patented processes produce sustainable cement and concrete that cures using CO₂. Combined, these technologies reduce carbon emissions up to 70% and recycle 60-80% of the water used in the production of concrete. Based in Piscataway, N.J. (USA), Solidia’s investors include Kleiner Perkins Caufield & Byers, Bright Capital, BASF, BP, LafargeHolcim, Total Energy Ventures, Bill Joy and other private investors. Honors include: 2016 Sustainia100, 2015 NJBiz Business of the Year; 2014 Global Cleantech 100; 2013 R&D Top 100; 2014 Best Place to Work in NJ; 2014 CCEMC Grand Challenge First Round award; 2016 CCEMC Grand Challenge Second Round finalist; 2013 Katerva Award finalist; and MIT’s Climate CoLab shortlist. Follow Solidia Technologies at www.solidiatech.com and on LinkedIn, YouTube and Twitter: @SolidiaCO2.

Technologies for carbon emission valorization

LafargeHolcim and Solidia Technologies signed a first Joint Development Agreement in August 2013, followed by a Commercial Agreement in January 2015 in order to bring the Solidia cement and concrete solutions on the market.

The Solidia cement solution is a non-hydraulic binder that is produced in existing cement kilns using the same raw material used to make Portland cement (PC). The key difference is that the Solidia binder is produced using less limestone and at lower kiln temperatures. These factors translate into reduced CO₂ emissions during cement manufacturing (30% reduction), from 820 kg per ton of Portland cement in the most efficient kilns to 570 kg per ton of Solidia Cement.
The Solidia concrete solution is based on mineral carbonation of the non-hydraulic binder. The binder is mixed with aggregate and water, and is then reacted with CO₂ gas to form a durable matrix. The curing process captures up to 300 kg of CO₂ per ton of cement used.

Together, the Solidia cement and concrete solutions reduce the CO₂ footprint by up to 70% when compared to conventional cement and concrete products.

The advantages to precasters are multiple:

- **Full strength in concrete parts achieved within 24 hours** (compared to 28 days for PC-based concrete). This permits just-in-time manufacturing and a significant reduction in inventory cost.
- **Concrete waste is virtually eliminated and equipment cleanup time is significantly reduced because the concrete does not harden until it is exposed to CO₂.**
- **The final precast products present better aesthetics than PC-based concretes (no efflorescence, better pigmentation, and better color grading).**

The first two non-hydraulic cement production campaigns were performed in the **Whitehall (USA) and Pecs plants (Europe)** of the LafargeHolcim group. The first precaster (in the USA) has commenced concrete production using the Solidia cement and concrete solutions. Durability tests and characterizations are on-going according to the norms in place for PC, both in the USA and the European Union.

LafargeHolcim and Solidia acknowledge the European Union for its funding in the framework of LIFE Program under grant agreement N° LIFE15 CCM/FR/000116. This funding will help the development of Solidia solution in Europe.

**Key words:** Mineralization, carbonation, Carbon Capture & Use, CO₂, precast, cement

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Heating, cooling and storage of energy with concrete

BUILDINGS AS MICRO ENERGY-HUBS DELIVERING CLIMATE FRIENDLY SOLUTIONS

BENEFITS
Heating and cooling with concrete:

• Wellbeing through the use of efficient radiant heat
• Offers us energy efficient cooling
• Energy Storage (buffering) in Concrete
• Healthy indoor climate,
  • no (dust) turbulences
  • uniform heat distribution
• Use of ambient heat and renewable energy sources
• Heating and cooling with a single system
• Almost no additional construction measures

COMPLETED PROJECTS

Community centre in Hallwang, Austria
100% heated with solar energy via the use of active structural energy storage. photo credits Z+B

Multi-family house in Salzburg, Austria
Active structural energy storage & Heat pump combined with photovoltaics. Photo credits Z+B

Multi-family house Pschorngasse, Vienna
Active structural energy storage. Photo credits Z+B

Head quarter of Kirchdorfer Cement, Austria
Active structural energy storage. Photo credits Z+B
THE VÖZ DEMO-PROJECT:

Utilisation of excess peak electricity via concrete structures

One family house close to Vienna, ca. 120 m² living area
Passive house standard (concrete/ Liapor Composite Wall)

Construction: mid-July 2015 to mid-December 2015

Objectives:
• Energy supply solely via heat pump:
• Excess peak electricity from wind power - Ground collector (brine as a transport medium)
• Simplest possible Heating/cooling System
• Simplest possible control
• Most economic solution

Planning of the building services | FIN – Future Is Now, Kuster Energielösungen GmbH
Supporting research (simulation based Calculation kernel ) | Dipl.-Ing. Dipl.-Ing. Dr. techn. Simon Handler
Partner wind energy: W.E.B. wind energy company, Austria

Basis for the simulation for the one family house

(Source of data: [WEB15])
C³ – Carbon Concrete Composite

The building industry has hardly changed since the introduction of reinforced concrete. Due to corrosion the service life of reinforced concrete structures remains far behind earlier expectations - many buildings barely get older than humans and, additionally, have a high resource and energy consumption. More than 100 million cubic meters are built with reinforced concrete. It is therefore the most important building material in Germany. Concrete is the material most commonly used after water in the world which has always lead to a high consumption of raw materials. In addition it leads to enormous CO₂ emissions. The production of cement is responsible for 6.5% of the total carbon dioxide emissions. That is about three times the amount of carbon dioxide emitted by global aviation.

The great challenges of our time – environmental protection and the mitigation of the effects of climate change – cannot be mastered without changes in the construction industry. The vision: establishing a new way to build by using C³-carbon concrete composite. Concrete will replace steel in the long term. Since carbon does not rust, most of the concrete, which is only used to protect the steel from corroding, can be spared. Carbon reinforced concrete is sustainable, environmentally friendly, saves material and weighs less. This offers a wider variety for architectural designs. Light Building and concrete are no longer a contradiction, but the concept of the future.

By 2020, all conditions should be created to introduce carbon reinforced concrete onto the market. By 2025, the construction should be established permanently.

C³ – Carbon Concrete Composite is currently the largest research project in the German construction industry. The construction industry, with a turnover of approximately 10% of the gross domestic product and more than 330,000 companies, is the most important branch of industry in Germany. Approximately 6% of all employees work in the building industry.

The Federal Ministry of Education and Research is funding the project as part of the initiative 'Zwanzig20 – Partnerschaft für Innovation' (Twenty20 – Partnership For Innovation) with up to 45 million euros. All companies involved add another 15 million euros capital.

Goals
Along the entire value chain – from the basic materials to the finished building – the required knowledge must be gathered, completed by basic and applied research and transferred to the planning process, the design and the manufacture. Roughly 3,000 new jobs will be created and existing jobs will take on a new quality. The substantial quality of our buildings will increase while costs can be reduced and the resource consumption can be lowered. At the same time it has to be proved that buildings and components made of carbon reinforced concrete ensure all safety standards. This applies to all newly created buildings and components as well as for the repair and protection of existing structures e.g. bridges.

Thematic emphases

- Strategy: innovation management, development of organization and communication structures (e.g. knowledge transfer, network management, marketing, controlling)
- Structural engineering: development of testing and dimensioning concepts, standardization and development of guidelines, new planning and design concepts, quality management from raw material to product
- Mechanical engineering: development of new fiber based reinforcement structures, development of textile machines, development of industrial scale manufacturing processes, coating technology, recycling concepts
- Chemical Engineering: Development of raw materials, semi-finished products (yarn, rods), coating agents, adapted concrete mixtures
- Electrical engineering: development of functional integration (e.g.: sensors, heating, health monitoring, data transfer)

Partners
The interdisciplinary consortium currently consists more than 150 partners. They cover all essential and necessary areas of expertise vital for the C³ - project. There are various industries involved in addition to the construction industry such as chemistry, mechanical engineering, engineering, electrical engineering, and the organization and communication management. Also represented are the health, the education and the training and further education sectors. 71% of the partners are companies, 25% research institutions and 4% registered associations.

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Initiated by
Sponsored by
Awarded with
Bauxite residue

Not a hazardous waste, a valuable secondary resource with an image problem

Bauxite residue has a number of aliases. It’s also known as bauxite tailings, alumina refinery residue and a number of other technical sounding terms. But perhaps the most common one, which is descriptive if not very flattering, is red mud. In addition to its unflattering nickname, bauxite residue often gets described in the press (and even in some academic journals) in somewhat pejorative terms. One common label that gets wrongly attached to it is ‘hazardous waste’. A secondary resource is essentially a second hand primary resource. So ores, including bauxite are primary resources: things you can extract from nature and process to get something you want from them – in this case alumina. Bauxite residue is what’s left over, but there’s a lot of good stuff left in there. Firstly there’s all of the alumina which you couldn’t extract using the Bayer process – up to 20% of that. Then there’s a load of iron in there too – up to 50% iron oxide. Then there’s all the little stuff – the rare earth metals, the scandium, the titanium dioxide. Small concentrations yes, but that stuff is valuable.

If you think of bauxite as the turkey you have for Christmas dinner (at least in the UK!), bauxite residue is what’s left over after dinner. Dinner (the Bayer process) has taken away most of the nice white juicy breast meat (alumina), but there’s still a bit of that left – enough to make some sandwiches surely. Definitely worth keeping! Then you’ve got all of the dark meat from the legs and various other places around the carcass (iron), that’s not quite as good as the breast meat, but lovely in a turkey curry on boxing day (again a UK thing…). You’ve still got your nice surprises like the wishbone (REE’s/scandium/titanium). And then you can use all of the bones and the rest of the carcass to make a nice stock for soup (like you can use the remaining residue to make geopolymers).

No-one in the UK would ever dream of throwing away their Christmas turkey after dinner, which is why it’s such a tragedy that so much of the bauxite residue being produced worldwide is sitting in disposal areas. We here at the MSCA-ETN REDMUD project are working to come up with ways to make tasty things out of the alumina industry’s leftovers. Waste not want not, after all!

Project

To tackle its (critical) raw material dependency, Europe needs comprehensive strategies based on sustainable primary mining, substitution and recycling. Freshly produced flows and stocks of landfilled industrial residues such as mine tailings, non-ferrous slag and bauxite residue (BR) can provide major amounts of critical metals and, concurrently, minerals for low-carbon building materials. The European Training Network for Zero-Waste Valorisation of Bauxite Residue (REDMUD) therefore targets the vast streams of new and stockpiled BR in the EU-28. BR contains several critical metals, is associated with a substantial management cost, whereas spills have led to major environmental incidents, including the Ajka disaster in Hungary. To date, zero-waste valorisation of BR is not occurring yet. The creation of a zero-waste BR valorisation industry in Europe urgently requires skilled scientists and engineers, who can tackle the barriers to develop fully closed-loop environmentally-friendly recovery flow sheets.

Goals & challenges

REDMUD trains 15 researchers in the S/T of bauxite residue valorisation, with emphasis on the recovery of Fe, Al, Ti and rare earths (incl. Sc) while valorising the residuals into building materials. An intersectoral and interdisciplinary collaboration of EU-leading institutes and scientists has been established, which covers the full value chain, from BR to recovered metals and new building materials. Research challenges include the development of efficient extraction of Fe, Al, Ti and rare earths (incl. Sc) from distinct (NORM classified) BRs and the preparation of new building materials with higher than usual Fe content.
General workflow

Consortium

REDMUD draws its talents from 9 Beneficiaries, including 6 Research Institutes (KU Leuven (coord.), UHelsinki, RWTH Aachen, KTH, NTUA, UTartu) and 3 Companies (MEAB, Aluminium of Greece, Titan). Concurrently, REDMUD is strengthened with 4 additional Partner Organisations (UPatras, UAveiro, Bay Zoltan, Tasman Metals) and an Advisory Board. Funding: 3,7 M EURO

http://etn.redmud.org/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 636876.