

INNOVATION IN THE LIME SECTOR 2.0

The European Lime Association | Edition 2018



Innovation that delivers
on sustainability

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1. Lime Industry Sector



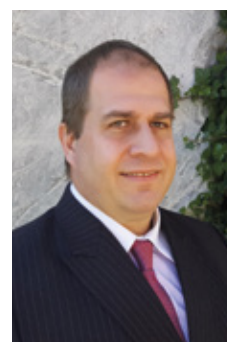
Executive summary

The European Union seeks to be the pioneer in climate change policies worldwide. The best tool to cope with climate change mitigation challenges and enhance European industry's competitiveness is innovation. For the second consecutive year, the European Lime industry (EuLA) in its effort to demonstrate its contribution and achievements in innovation, has compiled this report with publicly available information on projects dedicated to innovation and sustainability. Circularity is an environmental and economic concept that the lime industry has implemented from years in the quarry and operations.

Lime and limestone are basic enabling compounds which are necessary to many other industrial value chains. Without these base materials, many involved applications would simply not function in the same way. When you first consider the simplicity of the chemistry involved, innovation would not be the most likely word you would associate with this sector. However, the intention of this report is to Demonstrate how the sector manages to pursue innovation in many areas, from fuel consumption to process and resource optimization, application development, mining and production technology, to really have a sustainable innovation pipeline. This revised report has seen a major expansion in the countries that have submitted cases and also is showing how some traditional applications and areas of lime use have been given a new life in terms of the sustainability that they are providing to whole value chain and in the way that they are used today.

EuLA has in the last years set out on a path towards looking at opportunities where the sector can work in a more collaborative way in terms of innovation. It is impressive how member companies have embraced this initiative, and we are breaking down some of the conventional held notions that innovation must be a closely guarded company secret, to looking at some projects where no single member company could undertake the work alone, and to work together for the benefit of the sector.

If we go back to the goal of the first report, we were very much looking to demonstrate that the lime industry does innovate not only in how the industry engages in production but also in how the products are used. Today with this update we are showing that innovation is truly part of the day to day life of the industry, and that we are constantly looking at ways to improve the ability and sustainability of how we operate and how we enable the industries that rely on lime to utilize the products that we supply.



Julian Danvers
EuLA Innovation TF
Chairman

What is lime and its uses

Lime is a mineral product derived from limestone by an industrial process. Naturally occurring limestone is composed almost exclusively of calcium carbonate.

The lime production process is based on a chemical reaction induced by heating calcium carbonate (CaCO_3) to produce quicklime (CaO). Inevitably, this reaction also produces CO_2 . These emissions of CO_2 , which are inherent to the lime production process, are called process emissions. These process emissions alone constitute 70% of the total CO_2 emissions from the lime production process, and they cannot be avoided.

Lime industry is committed to reducing combustion and indirect CO_2 emissions, however the only possibility lies with the deployment of reliable and competitive carbon capture technologies, knowing that modern lime kil-

ns are already highly energy efficient (close to the efficiency limit).

The Innovation in the lime sector is achieved through:

- Sustainable production.
- Responsible resources management.
- Delivering quality added valued products.
- Creating value and support local economies
- Enabling the recycling of end of cycle materials in steel, glass and construction industry.
- Valorizing residues and turning them into raw materials for new processes, such as turning sulfur into gypsum for the plaster board industry.

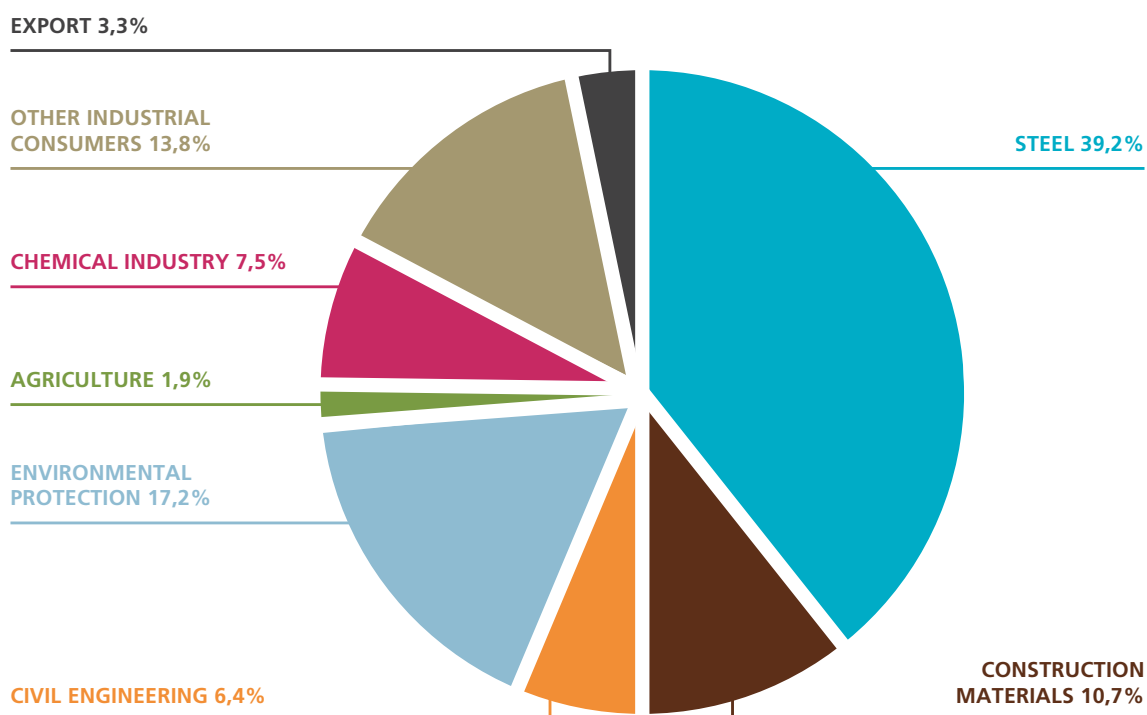
The lime industry has a long tradition in Europe. Lime is produced in industrial kilns all over Europe and is a fundamental, integral part of Europe's industrial base. As lime often goes unseen, its importance and versatility are largely unknown.



Due to its particular chemical characteristics, lime is a fundamental raw material used in a large number of industries and different economic activities, and is therefore essential to

many aspects of many people's lives. As an essential and enabling material, the use of lime for multiple sectors for the year 2016 is shown below.

SALES BY SECTORS, 2016



Did you know that...



...EACH EU CITIZEN USES AROUND 150GR OF LIME PER DAY?

A key enabling material for many industries (in e.g. steel, aluminum, paper, glass) **no high- grade steel without lime!**



A key product for environmental applications (in e.g. Flue gas cleaning, waste water treatment) **lime is the most economic material able to absorb many pollutants!**



A corner stone for **agriculture** (calcium for soil and crop improvement) as well as for animal food.



A multifunctional binder for construction (plasters & mortars) and public works (asphalt pavement and soil stabilization) **Lime is an efficient component for the road constructions and building isolation of tomorrow.**



An **essential mineral product**, but often unseen (in e.g. toothpaste, sugar, ceramics).

...LIME IS A SPONGE FOR CO₂?

In applications such as mortars and soil stabilization, lime functions as a carbon sink and absorbs up to 80% of the carbon emitted during its production process. In Precipitated Calcium Carbonate (PCC) for paper production, 100% of process CO₂ is re-absorbed.



**is the only mineral product that can be used
to produce steel and sugar in the same day**

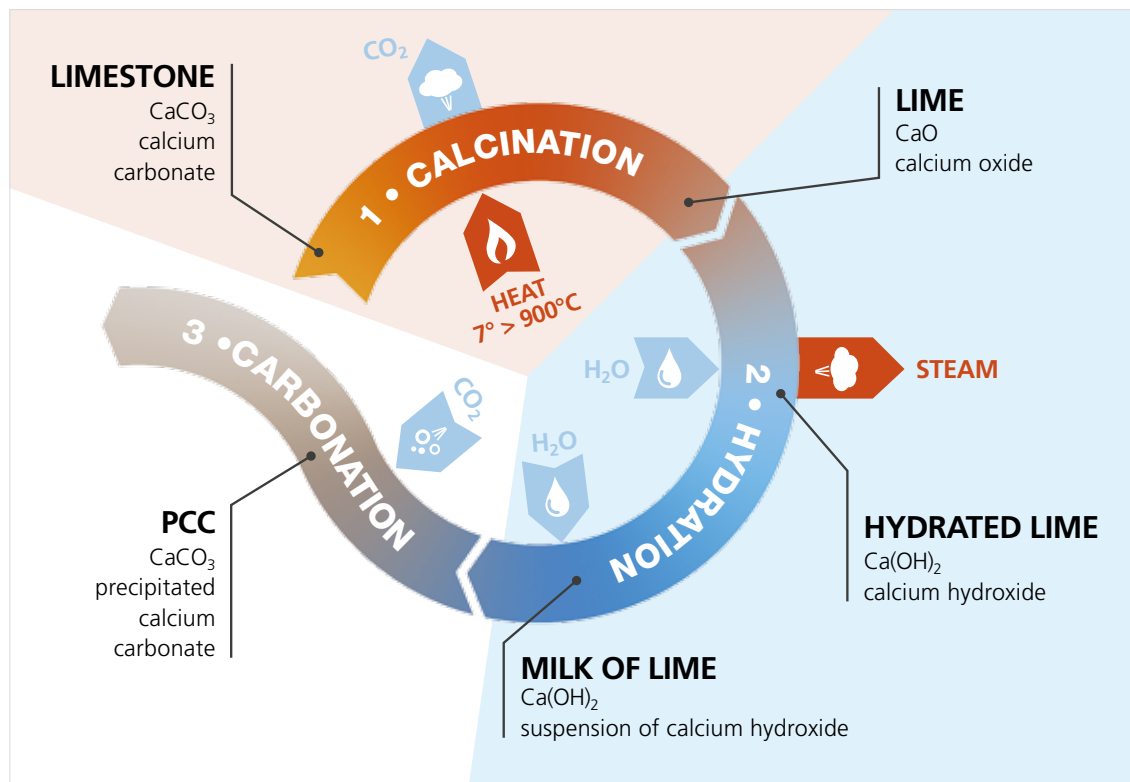
...LIME IS THE MATERIAL HELPING TO PROTECT OUR ENVIRONMENT?

Environmental applications have been the main driver for new lime applications in recent. Acid rain causes lakes and streams to become acidic and can damage trees. Lime is used to treat industrial waste gases to remove acidic gases to reduce acid rain and so protect our forests.

...68% OF LIME IS RECYCLABLE?

Lime is used as an input in a wide range of applications and end-products. Most of those are recyclable. The recycling rate of lime in steel applications for instance, is estimated to be around 95%, in civil engineering works (concrete, bricks, lime mortars and soil stabilization) the recycling rate of lime is estimated to be around 65%. Lime can also help to add value to some by-product and wastes. For example, the use of lime in flue gas treatment allows to create gypsum, which is reused in construction markets such as plasterboards. The treatment of sludge with lime allows to recycle some wastes into bio-solids which are re-used in agriculture.

CYCLE OF LIME



Innovation in lime sector

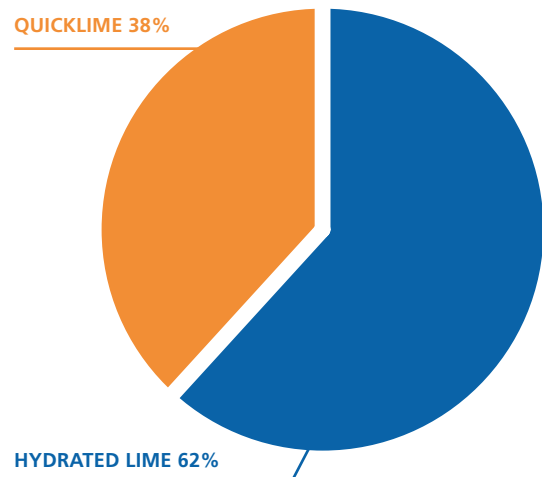
The lime sector is innovative and this can also be seen in the number of applications submitted by lime companies at the **European Patent Office (EPO)** and **World Intellectual Property Organisation (WIPO)** for the use of lime in multiple markets. Notably product innovation is taking place, as the sector provides highly standardized products to mature markets. Patents emerging from the industry itself target own manufacturing processes, product innovation and/or customization as well as innovation in lime use.

A comprehensive list of patents requested or granted inside and outside our industry is by far larger. A query launched at WIPO searching for "**Hydrated lime**" while excluding "**Quicklime**" returns some **1300 patents** from WIPO and EPO over the **last 20 years**. Similarly, a query searching for "**Quicklime**" while excluding "**Hydrated lime**" returns an additional **800 patents**. Important to stress is the fact that fundamental and applied Research & Development (R&D) is clearly developed at large scale by the large companies accounting for 67% of the total patents. The SMEs, use the patent or innovate on small scale.

Concerning products, the most significant innovation are "**High Surface Hydrates**" which feature an active reaction face of $> 35 \text{ m}^2/\text{g}$. Adding activated carbon and/or other ingredients can further customize these hydrates. They are applied to various flue gas streams in industry to effectively capture pollutants like HCl; Dioxins; Furans; Heavy Metals. Customized hydrates are considered BAT in several BREFs.

Other than in the EU, Lime is increasingly added to asphalt mixtures in the USA where Lime is known to enhance the durability of asphalt pavements. The field experience from North American State agencies estimate that hydrated lime – at the usual rate of 1-1,5% in the mixture (based on dry aggregate) – gives rise to the durability of asphalt pavements by 2 to 10 years. Neither US Life Cycle Cost Assessments in Hot Mixed Asphalt nor research published "Improvement of Quality of Asphalt by Addition of hydrated Lime – Experiments on a practical Scale" (Germany, AiF-Nr. 12542) are sufficiently acknowledged by public responsible officers across Europe.

PATENT APPLICATION FOR LIME PRODUCTS



REFERENCES:

- [1] Hicks R.G., Scholz T.V., 2003. Life Cycle Costs For Lime In Hot Mix Asphalt. Volume I – Summary Report. lime.org/documents/publications/free_downloads/lcca_vol1.pdf.
- [2] Schneider M., Schellenberg K., Ritter H.-J., Schiffrer H.-M., 2002. Verbesserung von Asphalteeigenschaften durch Zugabe von Kalkhydrat – Praxisversuch / Mischtechnik. In German. fg-kalk-moertel.de/files/2_2002_AiF_Projekt_12542.pdf.

Definitions

Anaerobic Digester (AD): is a process where micro-organisms break down some organic biomass in anaerobic conditions to produce biogas, $\text{CH}_4 + \text{CO}_2$.

Best Available Techniques (BAT): are drawn up for defined activities and describe, in particular, applied techniques, present emissions and consumption levels, considered for the determination of best available techniques as well as BAT conclusions and any emerging techniques, giving special consideration to the criteria listed in Annex III of 2010/75/EU Directive [3].

Biomass: refers to any source of organic carbon that is renewed rapidly as part of the carbon cycle. is derived from plant materials but can also include animal materials. **1st generation biomass/biofuels:** first generation biofuels are made from the sugars and vegetable oils found in arable crops, which can be easily extracted using conventional technology. **2nd generation biomass/biofuels:** known as advanced biofuels, are fuels that can be manufactured from various types of biomass. Second generation biofuels are made from lignocellulosic biomass or woody crops, agricultural residues or waste, which makes it harder to extract the required fuel.

Carbon Dioxide Storage Mineralisation (CSM): an alternative to conventional geologic storage is carbon mineralization, where CO_2 is reacted with metal cations to form carbonate minerals. **Ex situ CSM:** the carbonation reaction occurs above ground, within a separate reactor or industrial process. **In-situ CSM:** in situ mineralization, or mineral trapping, is a component of underground

geologic sequestration, in which a portion of the injected CO_2 reacts with alkaline rock present in the target formation to form solid carbonate species.

Carbonate looping: in the Carbonate Looping Process lime (CaO) reacts with CO_2 from the flue gas in a fluidized bed reactor (Carbonator) producing limestone (CaCO_3). CO_2 -free flue gas is released into the environment. In the second reactor (Calciner) the limestone is calcined and thereby CO_2 is released. The newly formed lime is lead back into the first reactor and consequently the loop is closed. In a third reactor (Combustor) coal is burnt with air and the heat is indirectly transferred to the Calciner to satisfy heat requirements for the calcination process.

Carbonation: is the natural process in which calcium hydroxide reacts with carbon dioxide and is transformed into calcium carbonate. The carbonation reaction in mortars and other alkaline materials consist of diffusion of the CO_2 through the pore structure and its dissolution in the capillary pore water where its reaction with calcium hydroxide occurs with the precipitation of calcium carbonate crystals (CaCO_3) known as hardening mechanism. Quicklime reaction: $\text{CaCO}_3 + \text{heat} \Rightarrow \text{CaO} + \text{CO}_2$; Hydrated lime (slaked lime) reaction: $\text{CaO} + \text{H}_2\text{O} \Rightarrow \text{Ca}(\text{OH})_2$; Carbonation reaction: $\text{Ca}(\text{OH})_2 + \text{CO}_2 + \text{H}_2\text{O} \Rightarrow \text{CaCO}_3 + 2\text{H}_2\text{O}$.

Circular economy: is a policy definition used for a regenerative system in which resource input, waste, emission, energy leakage are minimized by closing, narrowing material and energy loops.

Definitions

Combined heat and power (CHP): cogeneration or combined heat and power is the use of a heat engine or power station to generate electricity and useful heat at the same time.

Direct Separation Reactor (DSR): refers to re-engineering the existing process flows of a traditional calciner by indirectly heating the limestone via a special steel vessel. This system enables pure CO₂ to be captured as it is released from the limestone, as the furnace exhaust gases are kept separate.

Emerging technologies: are those technical innovations which represent the potential for progressive developments within a field for competitive advantage.

Flue gas treatment (FGT): industrial processes generate flue gases. These often contain pollutants such as sulfur oxides (SO₂ + SO₃), hydrochloric acid (HCl), hydrofluoric acid (HF) as well as heavy metals, dioxins and furans. Lime, hydrated lime and limestone-based products are highly efficient reagents for capturing contaminants and are used in flue gas treatment (FGT). When mixed with other components, they also remove so-called micro-pollutants.

Innovation: refers to the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (OECD & Eurostat. 2005, p. 146). The innovation can be grouped into: 1. Product Innovation; 2. New innovative methods of production; 3. Market innovation;

4. Organisation innovation; 5. System Innovation (MinGuide. 2016, p. 10-14).

Organic Rankine Cycle (ORC): is a well-known and widely spread form of energy production from heat, mostly in biomass and geothermal applications, but great rises in solar and heat recovery applications are also expected.

Public Private Partnership (PPP): is a broad term is used for a funding model involving partners from private and public entities that includes funding, planning, building, operation, maintenance and divestiture of projects of interest. PPP arrangements are useful for large projects that require highly-skilled workers and a significant cash outlay to get started.

Return on Investment (ROI): is a profitability ratio that calculates the profits of an investment as a percentage of the original cost over time.

Technology assessment (TA): is a scientific, interactive, and communicative process that aims to contribute to the formation of public and political opinion on societal aspects of science and technology.

Technology life-cycle (TLC): describes the commercial gain of a product through the expense of research and development phase, and the financial return during its "vital life". Some technologies, such as steel, paper or cement manufacturing, have a long lifespan (with minor variations in technology incorporated with time) while in other cases, such

as electronic or pharmaceutical products, the lifespan may be quite short.

Technology Readiness Level (TRL): are determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities. TRL are based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology (EARTO, 2014).

Technology transfer, known also as transfer of technology (TOT): is the process of transferring (disseminating) technology from the places and ingroups of its origination to wider distribution among more people and places. It occurs along various axes: among universities, from universities to businesses, from large businesses to smaller ones, from governments to businesses, across borders, both formally and informally, and both openly and surreptitiously.

REFERENCES:

- [3] Best Available Techniques (BAT) Annex III of 2010/75 /EU Directive.
- [4] EARTO. 2014. The TRL scale as a Research & Innovation Policy Tool: EARTO Recommendations. Pp. 17. earto.eu/fileadmin/content/03_Publications/TRL_EARTO_Recommendations_-_Final.pdf.
- [5] EC. 2013. European Commission. HORIZON 2020-WORK PROGRAMME 2014-2015. 19. General Annexes Revised. Pp. 36.
- [6] EC. 2015. European Commission Decision C (2015) 8621 of 4 December 2015.
- [7] MinGuide. 2016. The MIN-GUIDE common approach. Deliverable 1.1. Version 1. Pp. 49.
- [8] OECD & Eurostat. 2005. Oslo Manual: Guidelines for collecting and interpreting innovation data. Pp. 166.



2. Innovation in Quarry

- Less fines
- Blast-Control
- Repurpose lime by-products
- Noise barriers
- Water Management Platform
- Life in Quarries
- Drinking water from quarry
- Gravity conveyer belt
- Resource optimisation
- Water Management
- Community relations



LESS FINES • Less fines production in aggregate and industrial minerals industry

cordis.europa.eu/project/rcn/54228_en.html

Scope of work

Every year in Europe the aggregate and industrial minerals industry produces around 1.35 billion tons of blasted rock. During the blasting operations, an amount of around 20% of the material is smaller than 10 mm to 20 mm and is too fine to be used efficiently and generally goes in the waste dump. The aim of the project is to reduce the amount of lost material by 50% through the adaptation of the explosives and timing procedure to the natural breakage characteristic of the rock.

The project consortium is formed of nine partners from four EU member states and consists of the two major producers of explosives in Europe, a large Swedish limestone producer, a Spanish cement and aggregate producer with 11 quarry sites and an Austrian aggregate producer (SME operation) with 3 quarries. Four blast research centers are partners in the project.

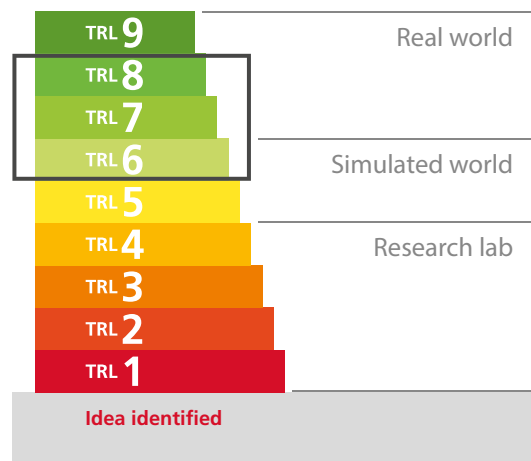
Status of the project

Project finalized in 2004. The following deliverables can be reported:

- Mining engineers defined a comprehensive methodology entitled Energy Controlled Blasting (ECB) was defined (Leoben); designed by the blast centers and tested at quarries [9, 10].
- Important insight into the way rocks fracture and disintegrate when blasted was gained by performing a battery of physical and chemical analyses on several rock samples in the laboratory.
- The environmental benefit of ECB is a significant reduction in the amount of fine material produced.
- Economic benefits to the quarrying operation in the form of reduced operating costs and increased output were also observed.

Type	Demonstration
Partners	Leader: Montan University (AU) Lime: Nordkalk (FI)
	
Funding	EU / FP5 / GROWTH Total project: 4.1 Mill EUR EU contribution: 2.4 Mill EU
	
Duration	03.2001 – 06.2004
TRL	Technology Readiness Level: TRL 6-8

Commercial deployment



Contribution to

Raw material optimization – Environmental protection – Optimize production flow – Technology transfer – Safety – Replicable results – Automatization – Circular economy.

REFERENCES:

[9] Less-fines 2004. Project summary: Reducing the environmental impact of rock quarries. cordis.europa.eu/result/rcn/81974_en.html.

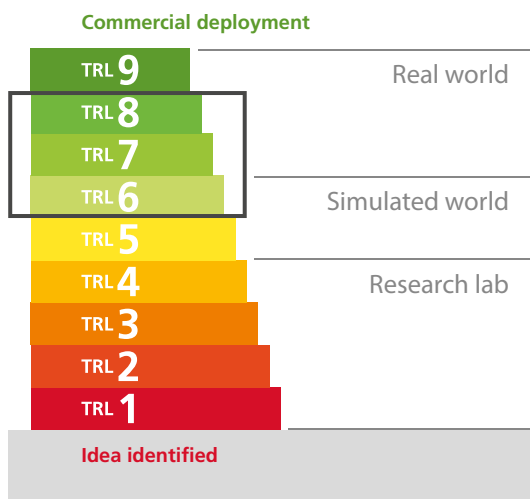
[10] Less fines. 2004. Project summary: Accurate predictions of rock fragmentation after blasting. cordis.europa.eu/result/rcn/82032_en.html.

BLAST-CONTROL ●

Productivity improvement in open-pit mining and quarrying by means of an integrated control system for blasting and production-flow optimization

cordis.europa.eu/project/rcn/44832_en.html

Type	Demonstration
Partners	Leader: Nitro Bickford (FR) Lime: Calcinor & Lhoist
	
Funding	EU / FP4 / BRITE Funding rate: not reported
	
Duration	09.1998 – 12.2001
TRL	Technology Readiness Level: TRL 6-8



Contribution to ●

Environmental protection – Optimize production flow – Materials technology – Safety – Raw material optimization – Replicable results.

REFERENCES:

[11] Blast-Control project summary: 2002. Blast oriented production control system for open-pit mining and quarrying. Pp. 1. cordis.europa.eu/project/rcn/44832_en.html.
[12] Blast-Control project summary: 2002. Neural Network system for fragmentation prediction. cordis.europa.eu/result/rcn/27963_en.html.

Scope of work ●

The use of blast, in open-pit exploitations is a challenging task due to rock-fragmentation issued from the blast and to rock-mass hazards. To respond to European environmental constraints, the control of risks and valorization of natural resources need to be addressed together.

This project aim to support industry for monitoring and blasting control to optimize the primary production process, including drilling, blasting, loading, haulage and primary crushing, as well as the impact of fragmentation of blasted rock. Solving this problem requires, first, to be able to monitor and to quantify continuously the impact of fragmentation on basic operations, and, secondly, to guarantee with blasting the resulting fragmentation which optimizes production-flow and minimizes costs.

Status of the project ●

Project finalized in 2001. The following deliverables can be reported:

- Blast oriented production control system adapted for open-pit mining and quarrying industry operations [11].
- Assist to rebuild the primary production chain starting with blasting, which is often discontinuous and fuzzy for analysis.
- It allows to control and analyze productivity of each single production chain starting at the blast stage.
- It allows to improve productivity of each single production chain, by acting on blasting or other production parameters.
- A methodology for systematic and accurate assessment of the blast geometry.
- Measurement and software system for blast control and blast design.
- Neural Network system for fragmentation prediction aligned with the continuous data acquisition methodology [12].
- The system is operational and is linked to the database of the production control system.

REPURPOSE LIME BY-PRODUCTS ●

ely-keskus.fi/web/ely/ely-kaakkois-suomi

Scope of work

The optimization of the waste flows is a challenge during and after the operations to manage properly the raw material deposit and extend the lifetime of the quarry through better management of waste and by-products [13]. These practices were used by industrial minerals industry extensively even before EU policies (i.e. Waste Management BREF (2006) Mining Waste Directive (2006)) were in place. This project illustrates the repurposing and resource optimization from a limestone quarry operations in Finland by Nordkalk Corporation.

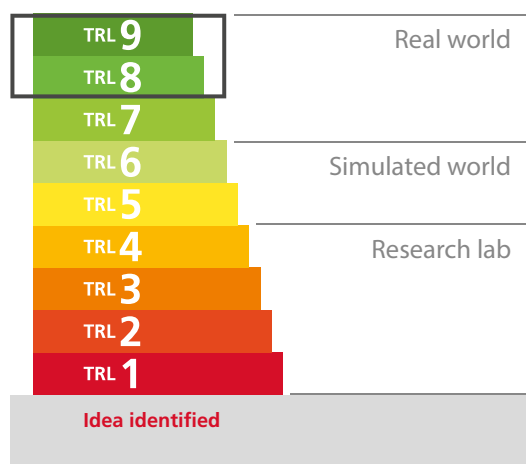
Status of the project

Ongoing practice. The following deliverables can be reported:

- The limestone, the main product, is extracted and processed (grounded and the concentrated calcite is separated from the slurry by flotation) in Finland operations and filter sand are a by-product estimated to be around 100 KT/year [14].
- The overall volume estimated for these by products is estimated in the range of 5.7MT from 1960 onwards [13].
- Filter sand minerals (such as calcite, wollastonite, dolomite and silicates) are produced as a by-product in the extraction and processing stage. Since the 1960's a part of this filter sand has been used as a part of mixture of a lime fertilizer for organic agriculture as certified from Finnish Food Agency. The use for these two markets is 50/50.
- The company has also commercialized the filter sand to be used in earth and environmental construction.
- This is a good example of resource efficiency and repurposing of mineral material and minimize the waste volumes.

Type	Innovation action
Partners	Leader/Lime: Nordkalk (FI) ↔ Nordkalk
Funding	Own company project Total project: not applicable
Duration	1960 – to date
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



Contribution to

Raw material optimization – Lime by-products
– Earthworks – Sand filter – Waste reduction
– Multiple policy objectives.

REFERENCES:

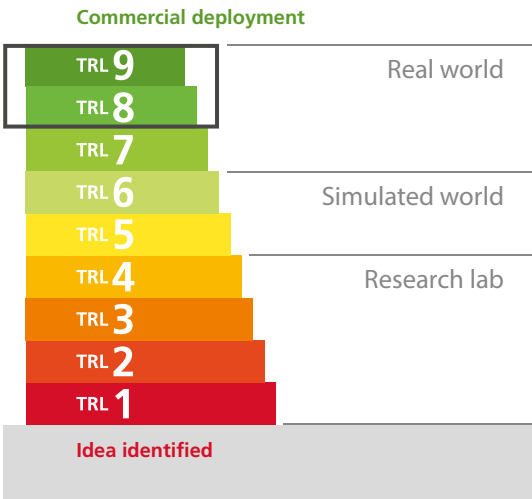
- [13] Kojo I.V., Reuter M.A., Heiskanen K., 2013. Some examples of reuse, repurposing and recycling of minerals to improve the resource efficiency in mining: Nordkalk, Finland, commercialization of filter sand. 6th International Conference on Sustainable Development in the Minerals Industry (SDIMI), 30 June – 3 July 2013, Milos (Greece). Platform presentation. Pp. 4.
- [14] Kajoniemi M., Eskelinen A., Keskitalo K., Rajamäki R., Rautanen H., Sahala L., Sääksniemi E., Timperi J., Tos-savainen J., Vallius P., Vuokko J. 2008. Coordination of Groundwater Protection and Stone Conservation – South Karelia final report. Pp. 120.

NOISE BARRIERS ●

Noise barrier at Miedzianka (Poland)

nordkalk.com/sustainability/environmental/reducing-dust-noise-vibration

Type	Innovation action
Partners	Leader/Lime: Nordkalk (PL, FI) ◀▶ Nordkalk
Funding	Own company project Total project: not reported
Duration	2012 – 2016
TRL	Technology Readiness Level: TRL 8-9



Noise barrier at Miedzianka (Poland).

Contribution to ●

Nuisance avoidance measures – Community relations – BAT.

REFERENCES:
[15] Nordkalk Sustainability Report 2016. Pp. 8.

Scope of work ●

To avoid nuisance towards the local, multiple projects have been developed in coordination with the local communities and authorities. Sound insulation is improved by constructing noise barriers, planting trees and using various noise-damping materials at crushing plants, conveyor belts and loading places. In locations near residential areas, there are restrictions on night-time operations to avoid disturbances to the local residents.

Status of the project ●

- Vibration caused by blasting is measured; in Lohja, Finland, e.g. continuous measuring is carried out at three locations near the mine and at several temporary measuring points. Based on the results, necessary changes are made to blasting methods to reduce the amount of vibrations. Nordkalk has ensured the readiness of its production facilities for the Best Available Techniques (BAT) obligations deriving from the Industrial Emissions Directive (IED) [15].
- Noise barriers or acoustic baffles are the best way to “fight” noise, which is emitted by transport, trucks, trains and loaders. In 2015, the Miedzianka Plant in Poland finished building 700 metres of wall baffles along its traffic routes. The seven meters high walls are made of sound-absorbing material. The measurements carried out after the installing of acoustic baffles fulfilled the requirements of the contract concerning the reduction of noise emissions. In 2016, additional actions were taken to further reduce noise emissions at night. As a continuation to the sound-absorbing barriers built a year earlier, two new environmental investments were finished. Special octagonal noise reducers were installed on the upper edge of the barriers to absorb diffracted sound waves into the sound-absorbing mineral wool plate. Another improvement was replacing an old steel element gate with acoustic panels. The noise measurements carried out after finalizing the construction showed significant reduction of the noise level.

WATER MANAGEMENT PLATFORM ●

Multi-stakeholder Water Management Platform to manage water resources for quarrying activities

Scope of work

The operation of multiple stakeholders (drinking water. planning authorities, mining company) within the same area and the competition for water resources is a challenging task, which requires a multi-stakeholder management system that accommodates needs and secures access to all concerned stakeholders. The Water management projects consist in illustrating the establishment of this system and the modus operandi.

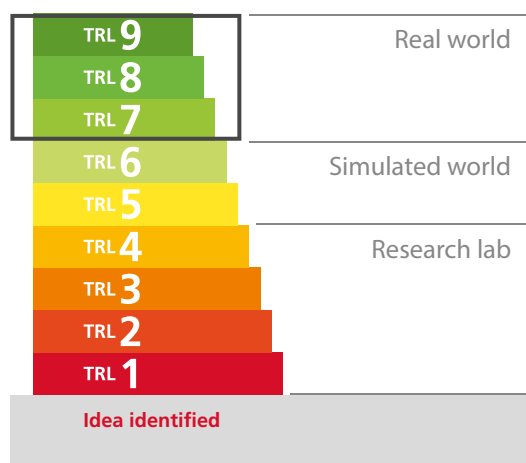
Status of the project

Water management platform is operational and the following can be reported:

- Motivation of all the working group members to put resources and arrive at a solution despite the sectoral differences to create a real common spirit between all the members towards a final common solution operational to all.
- All stakeholder inclusive platform that allowed the concerned stakeholders to establish a level of trust to share their respective data.
- The data sharing process, allowed the concerned stakeholders to explain their concerns and demands.
- The selection of a common and neutral Engineering Company to conduct the feasibility study.
- This exchange platform allowed the regional authorities to have a helicopter view and understand all constraints and demands and make the best decision on the condition to access the water resource.
- This platform allowed to ensure a cohesion between legislations (Ex: conditions of permit for water pumping in quarry are not the same as for a drinking water permit). This process allowed to find a pragmatic and compatible legal solutions [16].

Type	Demonstration
Partners	Leader/ Lime: Carmeuse (BE) 
Funding	Own company project Total project: not reported
Duration	2003 – 2011
TRL	Technology Readiness Level: TRL 7-9

Commercial deployment



Contribution to

Raw material optimization – Water management platform – Stakeholder involvement.

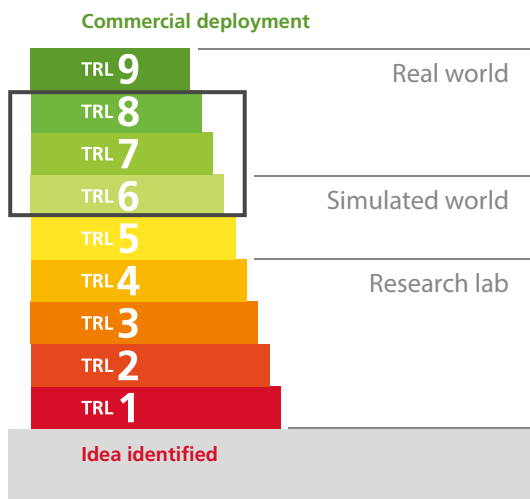
REFERENCES:

[16] Despotou E., 2012. Resource Efficiency for mining and processing in the lime industry – case studies. IMA-Europe 2012 Conference: Resource efficiency and the contribution of industrial minerals. 14 November 2014 in Brussels (Belgium). Platform presentation.

LIFE IN QUARRIES ●

lifeinquarries.eu

Type	Demonstration
Partners	Leader/Lime: Fediex (BE) 
Funding	EU / LIFE+ Total project: 5 Mill EUR EU contribution: 2.8 Mill EUR 
Duration	02.2015 – 01.2020
TRL	Technology Readiness Level: TRL 6-8



Map of Walloon quarries contributing to the project.

REFERENCES:

[17] Life in Quarries. 2016. ec.europa.eu/environment/life/project/Projects/index.cfm.

Scope of work ●

The LIFE IN QUARRIES project aims to develop biodiversity in active quarries by:

- Testing and defining methods for the restoration, maintenance and management of pioneer species and habitats.
- Testing and defining methods for preparing the physical quarry infrastructure during exploitation processes, to facilitate the establishment of restoration plans that will increase ecosystem services and biodiversity following exploitation.
- Identifying lock-in situations and challenges for biodiversity development in active quarries such as legal constraints, lack of biodiversity management awareness etc.
- Developing the awareness of quarry managers, public administration managers and other local stakeholders for biodiversity management.
- Demonstrating best practices of adapting management throughout the complete exploitation process for up to 24 Belgian quarries and sharing this experience in the European context.

Status of the project ●

Project is ongoing. Key objectives consist of:

- Training for CEOs and staff members of the 24 Walloon quarries (see fig.) and six EU quarries, including workshops, development of factsheets and guidelines for the creation and management of temporary habitats in quarries. Development of supporting videos and a picture database aimed at species recognition for quarry workers.
- Analysis & inventory of actual and potential ecosystem services and green infrastructure developed by the extractive industry.
- External communication, dissemination for other EU quarries and experience-sharing events with relevant partners in France, Germany [17].

Contribution to ●

Nature preservation – Temporary habitat – Biodiversity issues – Ecological coherence – Industry – Mining – Quarrying – Renaturation.

DRINKING WATER FROM QUARRY

The town of Lohja (Near Helsinki) acquires water from Nordkalk quarry and uses it as drinking water

nordkalk.com/sustainability/community/water-for-lohja

Scope of work

More than one million cubic meters of groundwater is pumped up yearly from the underground mine. About half of the water is delivered to the municipal waterworks, where it represents 23% of all raw water received. It is filtered through a sand bed before being led to the water distribution system.

Status of the project

- The Tytyri plant itself uses some 30.000 m³ of water annually, also from the mine, but through a separate pumping station. The surplus water – about half a million cubic meters – is directed to the nearby lake Lohjanjärvi. This is mostly groundwater, but it includes a small portion of storm water gathered from the plant area. Yearly quality measurements show that the water released into the lake corresponds to household water quality.
- In Tytyri, there is also The Tytyri Experience including a museum and other activities. The Tytyri Experience is operated by the city and visited by more than 10.000 people annually. KONE Corporation's high-rise elevator test laboratory is located in old mine shafts. One of the elevators is used to transporting visitors to the Tytyri Experience [18].

Contribution to

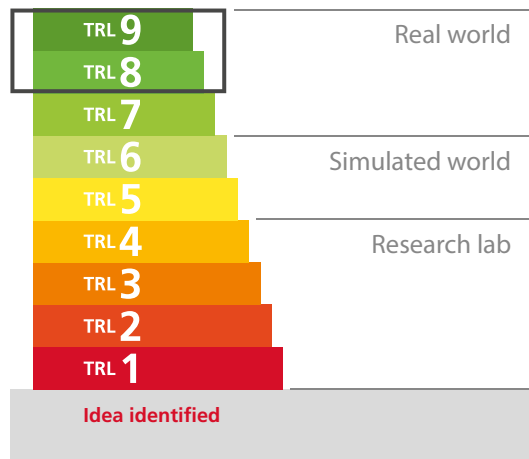
Stakeholder involvement – Community relations.

REFERENCES:

[18] Nordkalk Sustainability Report 2016. Pp. 37.

Type	Innovation action
Partners	Leader/Lime: Nordkalk (FI) 
Funding	Own company project Total project: not reported
Duration	2012 – 2016
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



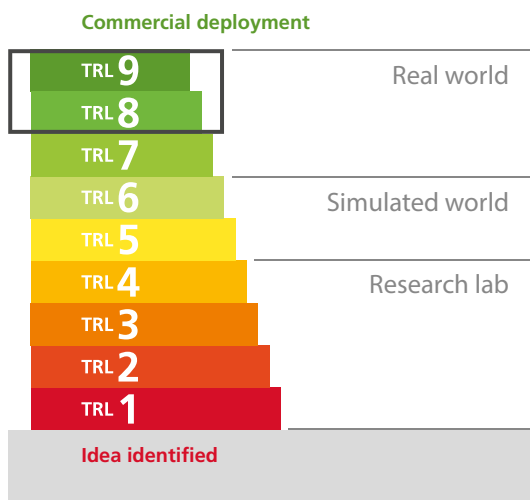
The town of Lohja acquires water from Nordkalk.

GRAVITY CONVEYER BELT ●

Gravity conveyor as a multi deliverable towards energy and environment footprint improvements

baumit.com
wopfingerbaustoffe.at

Type	Innovation action (demonstration)
Partners	Leader/ Lime: Baumit (AT) 
Funding	Own company initiative Total project: 0.75 Mill EUR
Duration	2001 – 2003
TRL	Technology Readiness Level: TRL 8-9



Dürrnbach quarry in Waldegg.

REFERENCES:

[19] Schwingenschlögl, R., Tisch, M.2002. Abbauoptimierung im Steinbruch Dürrnbachtal der Wopfinger Baustoffindustrie GmbH. 3M – Congress (Mining, Metallurgy and Mineral Industries), 31.05.2002, TU – Wien, Vienna (Austria). In German.

Scope of work ●

In view of improving the performance of this lime manufacturing site in Austria the company invested in a multiple retrofit project which consisted of: two new crushers, two shafts, and an underground tunnel for a gravity conveyor belt. All these investments provided multiple benefits from an energy, CO₂ improved performance for the company and nuisance avoidance for the local neighbors.

Status of the project ●

Project commissioned in February 2003 and is was part of an integrated investment to refit, boost and optimize the operations of the site. Key achievements of this project are:

- Installation of two crushers (primary and secondary crusher).
- Two shafts (diameter 4 m, depth 144 m).
- A new tunnel (727 m, with the existing tunnel more than 1000 m).
- A new conveyor gravity belt (distance between axis 1020 m, width of belt 1000 mm, 200 kW generative operation).
- The conveyor belt, working with gravity, about 200 MWh per year of electricity can be generated. More than 150 tons of CO₂ can be saved per year, using the Commission CO₂-emission per MWh of 0,76 t.

It was a company initiative to improve the environment footprint and energy savings for the production of limestone. With this project conveying of limestone by gravity, noise, dust emissions and other nuisances for the local community in the vicinity could be reduced substantially due to the smaller number of tracks transporting the raw material from the quarry to the processing facility [19].

Contribution to ●

Energy generation & efficiency – Truck avoidance – CO₂ avoidance – Dust avoidance – Nuisance avoidance – Refit project.

RESOURCE OPTIMISATION ●

Efficient use of natural resources

nordkalk.com/sustainability/environmental/efficient-use-of-natural-resources

Scope of work

Nordkalk strives to optimize the use of all the extracted /processed raw materials, aiming for 100% material efficiency, which is sound from both financial and environmental point of view.

Status of the project

- The material-efficiency efforts include using all by-products: wall rock that is extracted in addition to regular limestone, fine sand produced in the flotation process, filter dust, which builds up in all lime kilns and at grinding plants, and residues created in lime burning and slaking. Nordkalk also assists its customers by handling their process by-products in a sustainable way.
- In 2016, Nordkalk was able to raise the material efficiency rate from 94.3% to 96.6%, thanks to focus on sales of lime kiln dust and especially of wall rock.
- Wall rock is used to build infrastructure, e.g. foundations for roads, airports and windmill parks. In addition to the Finland's domestic market, stone products are shipped e.g. to the Baltics and Russia for infrastructure projects.
- All of Nordkalk's stone material is CE marked, which supports sales, as does the growing environmental awareness in the society.
- Wall rock is typical of Finnish quarries for geological reasons. In the Lappeenranta and Pargas quarries, wall rock represents approximately one third of all quarried stone products [20].

Contribution to

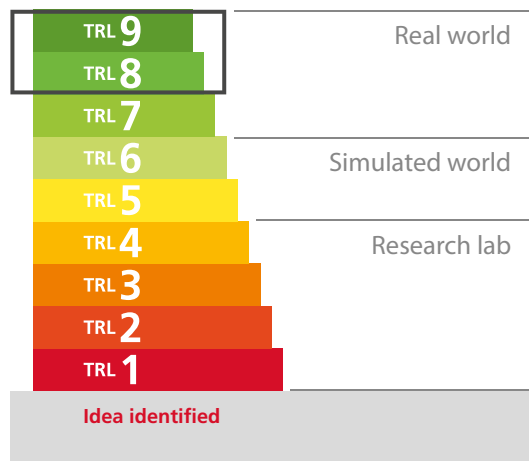
Resource optimization – Certification – Zero waste quarry.

REFERENCES:

[20] Nordkalk Sustainability Report 2016. Pp. 10.

Type	Demonstration
Partners	Leader/Lime: Nordkalk (FI) ◆ Nordkalk
Funding	Own company project Total project: not reported
Duration	2012 – 2016
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



- Processed and sold stone (81,3%)
- To storage and disposal (2,4%)
- Utilised by-products (16,3%)



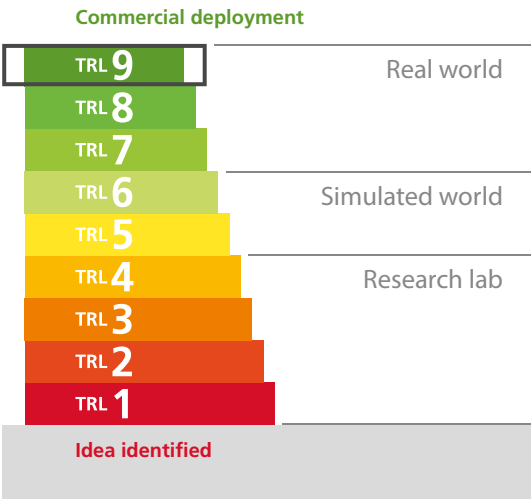
Material optimisation.

WATER MANAGEMENT ●

Water management at quarry post-closure

nordkalk.com/sustainability/environmental/planned-water-management

Type	Restoration
Partners	Leader/Lime: Nordkalk (SE) ◀▶ Nordkalk
Funding	Own company project Total project: not reported
Duration	2012 – 2015
TRL	Technology Readiness Level: TRL 9



An arched bridge has been built for more trout to be able to play further up the Klinthagen creek.

collected by counting the numbers of spawning pockets every autumn until two years after completion of quarrying [21].

Contribution to ●
Mitigation measures – Stakeholder involvement – Fish conservation.

REFERENCES:
[21] Nordkalk Sustainability Report 2016. Pp. 15.

Scope of work ●

The guiding principle in each quarry water management plans is to carry out operations with minimal negative impact on both the surface water and groundwater. Today, the lake in Klinthagen quarry holds about 2.5 million cubic metres of water. When the quarry is closed and the lake completely filled, the lake will accommodate about five million cubic metres and be Gotland’s deepest lake and the second largest lake in terms of volume after Lake Bästeträsk.

Status of the project ●

- In the autumn of 2015 a two-kilometre-long ditch was built to dewater the northern and central part of the quarry. When the pit is closed ditches will also be constructed to carry water to the pit exit point and onward to Klinthagen creek. The ditches create a self-regulating system with natural sedimentation of the water extraction.
- From the exit point the water will be transported to an area of maximally active wetland vegetation for further cleaning of the water downstream from the Klinthagen quarry and into the creek. Any limestone particles, clay particles and nitrogen resulting from limestone quarrying are removed, so that the water is crystal clear and has the same concentration levels as the natural creek water.
- An arched bridge has been built for more trout to be able to play further up the Klinthagen creek.
- Fish conservation efforts will be carried out in the creek, to promote spawning fish and other aquatic organisms. Spawning gravel has been deployed and ditches adjacent to the sea and farmland have been cleared. An arched bridge has been constructed under a minor road so that more trout will be able to spawn further up the creek. To promote the fry’s hatching period, small flows will be pumped out into the creek from April to midsummer. Information on how the trout’s spawning territories evolve over time, will be

COMMUNITY RELATIONS

Mining and community relations

carmeuse.com/neighbor-relationships

Scope of work

The operation of multiple stakeholders (drinking water; planning authorities, mining company) within the same area and the competition for water resources is a challenging task, which requires a multi-stakeholder management system that accommodates needs and secures access to all concerned stakeholders. The Water management projects consist in illustrating the establishment of this system and the modus operandi.

Status of the project

To preserve the technical aspects of the operations and minimize nuisance multiple measures are agreed with the local communities in the neighbor committee meetings and validated by the permitting authority and implemented by the mining company:

- The control blasting vibrations.
- Implementation of the programs to maintain the air quality.
- Dust emission can be minimized by different means: spraying products and roads, drilling with suction systems, having hooded conveyors and housings around crushing and processing units.
- To minimize noise, in multiple sites multiple measures were implemented: i.e. construction of a berm between the quarry and the houses, insulating the installations, replacing the traditional ear-splitting reverse horn by a softer horn that can be heard within the close surroundings of the truck and preventive maintenance of the installations by company staff [22].

Contribution to

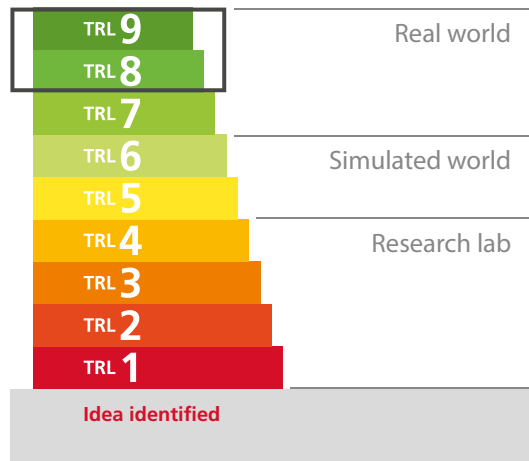
Nuisance avoidance measures – Stakeholder involvement – Community relations.

REFERENCES:

[22] Carmeuse. Case Study. Neighbor relationships. Pp. 1.

Type	Demonstration
Partners	Leader/ Lime: Carmeuse (BE) 
Funding	Own company project Total project: not reported
Duration	continuous
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



Carmeuse places a high value on both people and its relationship with local communities.

3. Process Emissions Mitigation

- AGICAL+
- BiOxySorb
- CaO₂
- CARINA
- CaLEnergy
- ECO
- ECO₂
- LEILAC
- SCARLET
- CSM
- CO₂Loop 4 energy storage
- NECAPoGEN 4Lime



AGICAL+ ●

Microalgae as CO₂ capture solution

ec.europa.eu/environment/life/project/Projects/LIFE10_ENV_BE_000696_FTR.pdf

Scope of work ●

The objectives of this project were two:

- Reducing the emissions of greenhouse gases and the consumption of fossil fuel linked to glass (high gas temperatures) and lime production with low temperatures).
- Capturing CO₂ in the flue gases using microalgae cultures, and then processing these microalgae to extract biofuel, to be used again in the product process to reduce the consumption of fossil fuels. The goal was to demonstrate that it is possible to capture 360 tonnes of CO₂ per year and per hectare of microalgae, thus producing 200 tonnes of biomass, and extracting up to 2460 GJ of biofuel.
- CO₂ is directly used by the algae in the photosynthesis process, and the heat contained in the gases is used for thermal control of the culture and to power surrounding process, thus maximizing the environmental benefit of the pilots. Hence, demonstration on both production processes would show the versatility of the technology.

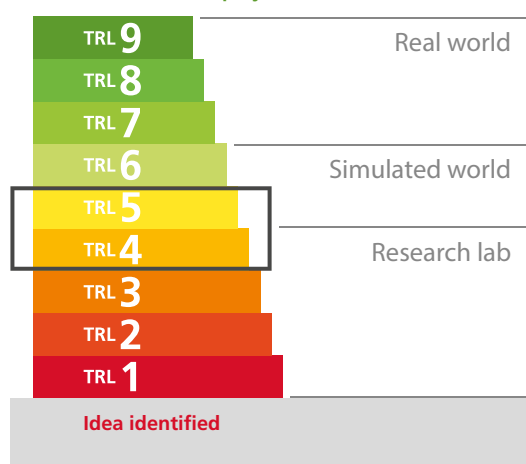
Status of the project ●

Project was terminated August 2013. Key deliverables of the project consist of:

- Two pilots. The pilots were to be implemented in two phases, first for the glass furnace, and then for the lime kiln, to allow for optimisation step. Therefore, the productivity of the first pilot was set at 150T/year, and the productivity of the second at 200 T/year.
- The evaluation of the pilot results led the partners to discontinue the project since.
- Throughout the 7 months testing period on the small pilot, the highest average yield was 10 tonnes/year/ha. Based on remaining findings the partners thus redesigned some parameters of the culture and estimated the absolute maximum potential biomass production to be 80 tonnes/ha/year. This would mean to capture 144 tonnes CO₂/year.
- Economic evaluation indicated that the cost of the biofuel produced would be in the order of 100-fold more expensive than commercially available (bio)fuels [23].

Type	Innovation action (pilot)
Partners	Leader: AGC (BE) Lime: Carmeuse (BE)  
Funding	EU / LIFE+ Total project: 9.2 Mill EUR EU contribution: 3.6 Mill EUR 
Duration	01.2011 – 11.2016 Project terminated on 08.2013
TRL	Technology Readiness Level: TRL 4-5

Commercial deployment



Pilot plant for the Algae growth.

Contribution to ●

Carbon sequestration – Renewable energy
– Emission reduction – Multiple policy objectives.

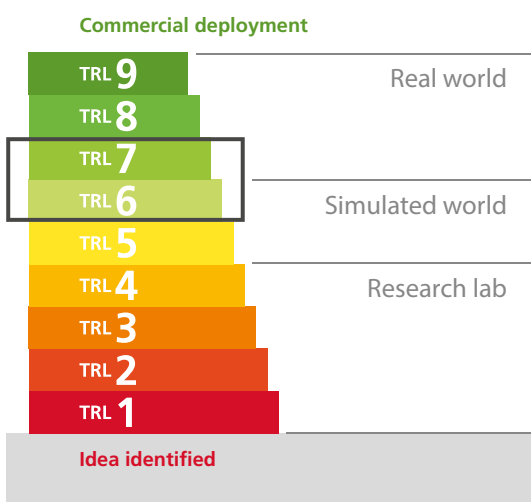
REFERENCES:

[23] AGICAL. 2013. Public version of Final Report. Project activities from 11/2011 to 08/2013.

BIOXYSORB • Biomass co-combustion under both air- and oxy-fuel conditions

bioxysorb.eu-projects.de

Type	Innovation action (pilot)
Partners	Leader: IFK (DE) Lime: Lhoist
	
Funding	EU / FP7 / RFCS Total project: 2.1 Mill EUR EU contribution: 1.3 Mill EUR
	
Duration	07.2013 – 06.2016
TRL	Technology Readiness Level: TRL 6-7



Contribution to

Energy efficiency – Emission control – Co-fired technology – Multiple policy objectives – Economic assessment.

REFERENCES:

[24] Spörl R., Pek S., Qin S., Maier J., Scheffknecht G. 2015. Acid Gas Control by Dry Sorbent Injection in Air and Oxy-Fuel Combustion. 5th Oxyfuel Combustion Research Network Meeting in Hongyi Hotel, Wuhan, China from 27-30th October 2015. Platform presentation.

Scope of work

The main objective of BiOxySorb is two-fold:

- Assess experimentally and techno-economically of 1st and 2nd generation biomass co-combustion under both air- and oxy-fuel conditions at various co-combustion ratios in combination with flexible, low cost SO_x, HCl and Hg emission control by sorbent injection.
- Economic low carbon power production and emissions control for future and flexible biomass co-fired power stations.

Status of the project

Project finalized in 2016. The following achievements can be reported:

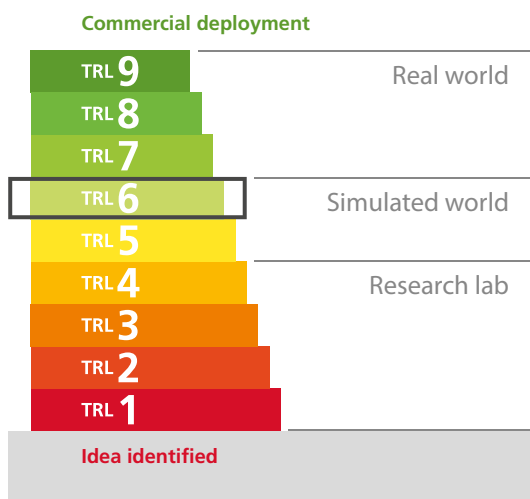
- Assessment behaviour of emission (PM, HCl, CO, NO_x, SO_x and Hg) of various first and second generation biomasses and co-combustion shares under air and oxy-fuel conditions.
- Choice and evaluation of sorbents (e.g. alkalines, earth-alkalines, and activated carbon or lignite/coal coke) and investigation of their application for control of HCl, SO₂, SO₃ and Hg emissions under air and oxy-fuel firing conditions.
- Investigation of necessary plant modifications for high thermal share biomass co-milling and co-combustion and for injection of sorbents.
- Techno-economical study of different degrees of biomass co-combustion and emission control by sorbent injection under air and oxy-fuel conditions. Utility and technology and supplies manufacturer (E.ON, LHOIST, GBS) will use the data generated in the experimental small, technical and large scale tests to assess the impact of the co-combustion and sorbents on full-cycle, full-scale power plants and to determine their impact on cycle optimization, ash valorisation and emissions control [24].
- Development of generic guidelines covering important considerations to be made in an overall economic optimisation of co-fired coal/biomass systems and the application of sorbents for emission control both with and without oxy-fuel combustion.

- [25] Abanades C. 2015. Progress on the calcium looping postconditions process. 6th High Temperature Solid Looping Cycles network meeting. 1-2 September 2015 at Politecnico di Milano in Milan Italy.

CARINA • Carbon Capture by Indirectly Heated Carbonate Looping Process

publications.europa.eu/en/publication-detail/-/publication/27bb757a-fc83-11e5-b713-01aa75ed71a1/language-en

Type	Innovation action (pilot)
Partners	Leader: TU Darmstadt (DE) Lime: Lhoist
	
Funding	EU / FP7 / RFCS Total project: 2.5 Mill EUR EU contribution: 1.6 Mill EUR
	
Duration	07.2010 – 09.2014
TRL	Technology Readiness Level: TRL 6



Contribution to

Energy efficiency – Retrofitting – Best available techniques – Carbon looping – Lime technology – Coal fired power plant.

REFERENCES:

- [26] Höftberger D., Karl J. 2013. Self-Fluidization in an Indirectly Heated Calciner, Chemical Engineering & Technology, Volume 36: 9. Pp. 1533-1538.
- [27] Junk M., Reitz M., Ströhle J., Eppe B., 2013. Thermodynamic evaluation and cold flow model testing of an indirectly heated carbonate looping process, Chemical Engineering & Technology, Volume 36: 9. Pp. 1479-1487.
- [28] Kremer J., Galloy A. Ströhle J., Eppe B., 2013. Continuous CO₂ Capture in a 1-MW_{th} Carbonate Looping Pilot Plant. Chemical Engineering & Technology. Volume 36: 9. Pp. 1518-1524.

Scope of work

To achieve a technological proof-of-concept and a detailed economical evaluation for the retrofit of an existing coal fired power plant. The process should yield higher plant efficiency and lower CO₂ avoidance costs than other CO₂ capture technologies which are currently under investigation. Screening of different sorbents (i.e. lime), to investigate the impact of the heat pipe surface on the attrition of the sorbents. Additionally, the fluidization behavior of sorbents with extremely low fluidization velocities and the selection of sorbents at reduced calcination temperatures will be examined. Investigating and testing a new concept with an indirectly heated calciner using heat pipes, offering even higher plant efficiency and lower CO₂ avoidance costs than the oxy-fired standard carbonate looping process.

Status of the project

Project finalized in 2016. The following achievements can be reported:

- The proposed concept is based on a fluidized bed heat exchanger system transferring heat from a combustor to the calciner by means of heat pipes. The main advantage of an externally fired calciner is the avoidance of oxygen production by an air separation unit. The estimated gain in electrical net efficiency is around 2-3% points, compared to a directly fired calciner [26].
- The heat input into the calciner is no longer effected directly, but indirectly by means of heaters. This results in a multitude of process engineering advantages.
- The standard carbonate looping promises low energy penalties for post-combustion CO₂-capture and is particularly suited for retrofitting existing power plants [27].
- The concept was tested at a 1 MW_{th} test plant at TU Darmstadt. The process optimization for reactor temperatures, fluidization velocity of the calciner and sorbent materials as well as a feasibility study for a full-scale plant was evaluated [28].

CALENERGY ●

Chemical Looping 4 Combustion Technology

netl.doe.gov/research/coal/energy-systems/advanced-combustion/project-information/proj?k=FE0009484

Scope of work

Alstom Power, through prior U.S. DOE funding, has been developing a limestone-based chemical looping combustion technology. The objectives of this project were to:

- Demonstrate in a large pilot (2-3 MW_{th}) a Alstom's Chemical Looping Combustion Technology with CO₂ Capture for New and Retrofit Coal-Fired Power.
- Enabling a full analysis of the process through an engineering system and economic study along with the development of a screening tool for process improvements.
- Analyses to include an evaluation of pressurizing the limestone chemical looping combustion process.

Status of the project

Project was terminated in 2017. Key deliverables of the project consist of:

- This project focuses on development of the limestone chemical looping combustion system [29].
- The low-cost limestone oxygen carrier along with less-expensive more-efficient reactors drives down capital and operating costs relative to conventional systems.
- This project addressed technology gaps and generating data to support scale-up via continuous, stable operation of a 1 MWe prototype system [30].

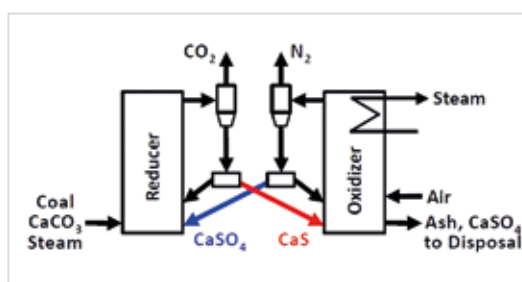
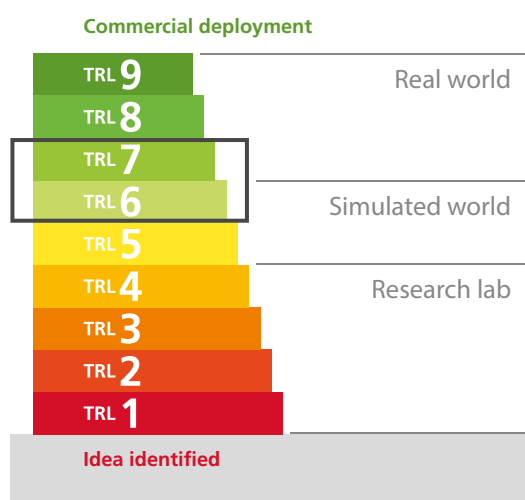
Contribution to

Carbon looping – Cost efficient solution – Lime technology – Energy efficiency.

REFERENCES:

- [29] Chamberland R. 2015. Alstom's Chemical Looping Combustion Technology with CO₂ Capture for New and Existing Coal-Fired Power Plants. Alstom Power, Inc., 2015 NETL CO₂ Capture Technology Meeting June 2015, Pittsburgh, PA.
- [30] Marion J. 2016. Alstom's Chemical Looping Combustion Technology with CO₂ Capture for New and Existing Coal-Fired Power Plants, GE Power, 2016 NETL CO₂ Capture Technology Project Review Meeting Aug 2016, Pittsburgh, PA.

Type	Innovation action (pilot)
Partners	Leader: ALSTOM (USA) Lime: Carmeuse 
Funding	USA (DoE) Programme Total project: 11.1 Mill EUR DoE contribution: 8.9 Mill EUR
Duration	10.2012 – 09.2017
TRL	Technology Readiness Level: TRL 6-7

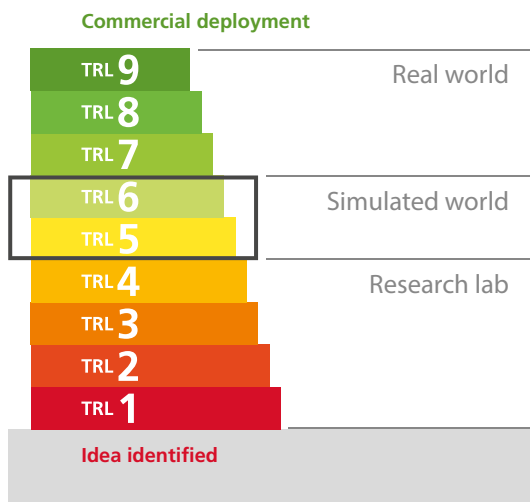


Alstom's LCL-C process implementation.

ECO ● Ecological CO₂ scrubbing (ECO)

fg-kalk-moertel.de/forschungsberichte.html

Type	Innovation action (pilot)
Partners	Leader/Lime: BV Kalk (DE)  
Funding	National: 0.5 Mill EUR 
Duration	05.2010 – 09.2012
TRL	Technology Readiness Level: TRL 5-6



CO₂ scrubber used at the waste water facility at Bad Orb, Germany.

Scope of work

The aim of this research project was to investigate the recycling of anthropogenic CO₂ into the natural carbon cycle using lime products. In practice, the capture of CO₂ from flue gases with the help of a limestone-CO₂-washing process similar to the naturally occurring carbonate weathering process. Subsequently after the CO₂ cleaning process the "produced" calcium bicarbonate-rich solution (mineralized water) should be returned to limnic and marine environments as natural buffer [31].

Status of the project

The project was finished in 2012. The CO₂ scrubbing process with limestone powder in solution was successfully demonstrated at the waste water facility in Bad Orb. During performance tests a reduction of CO₂ within the flue gas by up to 13% was achieved [32]. A four-five stage cleaning system could lead to a CO₂ reduction of up to 80%, as modeling and calculations revealed [32].

Contribution to

Carbon capture & use (CCU) – Natural carbon cycle – Lime technology – CO₂ reduction.

REFERENCES:

- [31] Haas S., Weber N., Berry A., Erich E., 2014. Limestone powder CO₂ scrubber: artificial limestone weathering for reduction of flue gas CO₂ emissions. ZKG (Zement Kalk Gips) International: 1-2. Pp. 64-72.
- [32] Haas S., Weber N., Berry A., Erich E. 2014. Limestone powder carbon dioxide scrubber as the technology for carbon capture and usage. Cement International: 12-3. Pp. 34-45.

ECO₂ ● Economical CO₂ scrubbing

fg-kalk-moertel.de/eco2.html

Scope of work

German economy relies heavily on an economically optimal solution for CO₂ reduction due to the withdrawal from nuclear power generation, almost 100% import of natural gas and the particularly high quotas for CO₂ reduction. This study assesses the following points by constructing a pilot plant CO₂ scrubber, chemical analysis and modeling:

- Optimization of CO₂ reduction performance,
- Verification of the ecological safety of process water (bicarbonate rich solution) discharge into limnic or marine waters.
- Modeling of the expected positive biochemical and ecological effects.

Status of the project

Project to be finalized in 12.2017. The following achievements can be reported:

- Cascaded scrubber system to remove CO₂ with limestone powder and produce ready to use buffered water.
- Pre-trial finished. Pilot plant build. Tests at IUTA (Duisburg)
- Bio- and ecological modelling to test the harmlessness of process water discharge and biochemical effects are ongoing.
- Location for pilot plant: coal-fired plant Wilhelmshaven (Uniper). Test campaign from March to June 2017 [33].

Contribution to

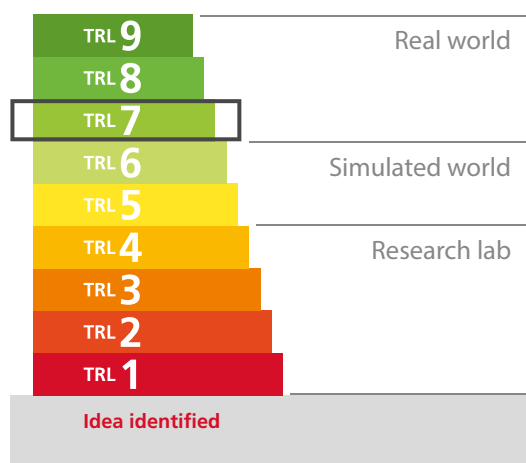
CO₂ reduction – Carbon capture and utilization (CCU) – Buffering of aquatic systems – Freshwater restoration – Multiple policy objectives.

REFERENCES:

[33] ECO₂ reports in German are available upon request. info@eula.eu.

Type	Innovation action (pilot)
Partners	Leader/Lime: BV Kalk (DE) 
Funding	National: 0.7 Mill EUR  AF
Duration	01.2015 – 05.2018
TRL	Technology Readiness Level: TRL 7

Commercial deployment



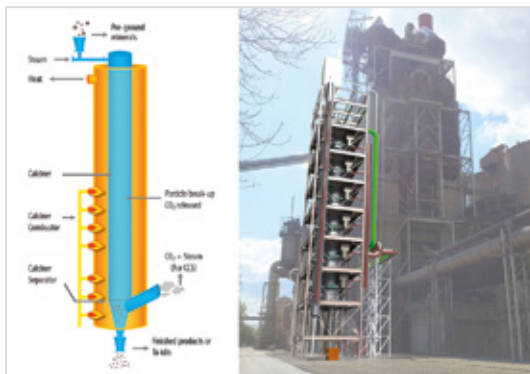
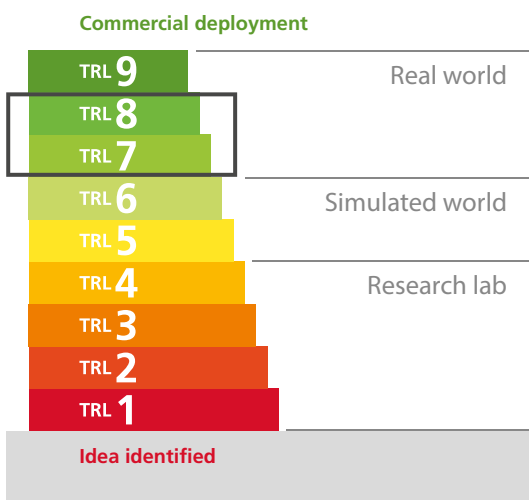
Pilot CO₂ scrubber of ECO₂ project, Wilhelmshaven coal-fired power plant, where pilot testing is carried out.

LEILAC

Low Emissions Intensity Lime And Cement

project-leilac.eu

Type	Innovation action (pilot)
Partners	Leader: CALIX (Australia) Lime: Lhoist & Tarmac
	
Funding	EU / H2020 Total project: 20.8 Mill EUR EU contribution: 11.9 Mill EUR 
Duration	01.2016 – 12.2020
TRL	Technology Readiness Level: TRL 7-8



Original DSR and DSR superimposed in the Lixhe plant.

[35] Edwards, P. 2017. Trapping process CO₂ emissions with the LEILAC project. Global Cement Magazine. globacement.com/magazine/articles/1004-trapping-process-co2-emissions-with-the-leilac-project.

Scope of work

The aim of the project is to develop in situ CO₂ capture process for lime/dolime and cement manufacturing:

- LEILAC will pilot the Direct Separation Reactor (DSR) advanced technology that has the potential to capture unavoidable process emissions and enable both Europe's cement and lime industries to reduce emissions by around 60% to 70%.
- Direct Separation provides a common platform for CCS in both the lime and cement industries. Calix's DSR technology has been used successfully to produce niche "caustic MgO" since 2012, while trapping the plant's process CO₂ emissions. The DSR is an in-situ CO₂ capture technique that requires no additional chemicals or equipment.
- LEILAC project innovation consists in the temperature scale up the DSR.

Status of the project

Project ongoing until 2020. The following progress can be reported:

- LEILAC will develop, build, operate and test at 8 tons per hour limestone feed rate (~100 tons per day lime) pilot plant at Heidelberg Cement's plant in Lixhe (BE), demonstrating that over 95% of the process CO₂ emissions could be captured [34].
- This technology can be proven at a suitable scale (approximately within 5 years for the lime industry, and likely more than 10 years for larger cement plant).
- In a lime plant, the unit will just replace the kiln. This design could also work with alternative fuels.
- Techno-economic analysis, and Life Cycle Analysis will be conducted at pilot scale to assess opportunity for technology's scale and deployment via a Roadmap [34, 35].

Contribution to

CCU/CCS – Process emissions reduction – CO₂ mitigation.

REFERENCES:

[34] Rennie, D. 2017. Trapping process CO₂ emissions with the LEILAC project. GLOBAL CEMENT: CO₂ CAPTURE. Pp. 16-21.

SCARLET

Scale-up of Calcium Carbonate Looping Technology for Efficient CO₂ Capture from Power & Industrial Plants

project-scarlet.eu

Scope of work

Calcium Carbonate Looping (CCL) is a technology tested for low-cost post combustion CO₂ capture for fossil fuels using limestone based solid sorbents. It combines the advantages of a small efficiency penalty of 5% to 7% points and a low CO₂ capture cost compared to competing technologies currently under development. First tests performed on the 1 MW_{th} scale have confirmed the feasibility of the technology.

- Long-term pilot testing of the CCL process at 1 MW_{th} scale at TU Darmstadt.
- Development and validation of scale-up tools and guidelines.
- Design, cost estimation, risk assessment study for a 20 MW_{th} CCL pilot plant.
- Techno-economic and environmental impact of commercial full scale CCL application.

Status of the project

Project finalized in 2016. The following achievements can be reported:

- Long-term pilot testing with hard coal and lignite. Four long-term CCL test campaigns, were successfully performed. In more than 1,200 hours, CO₂ was captured under a wide range of parameters achieving capture rates up of to 94% in the carbonator with a corresponding total capture efficiency of 97%. Sorbent analysis showed that steady-state conditions reached chemical sorbent.
- Scale-up and engineering of 20 MW_{th} pilot plant. The CCL process is being scaled up to a 20 MW_{th} pilot plant hard coal power plant as the host site in France. The process configuration was defined as well as heat and mass balances for design case and various load cases were created. The design of reactors as well as auxiliary systems and measurement equipment is ongoing.
- The SCARLET project has identified the technical and economic integration of CCL into a commercial power plant, a steel plant, or a cement plant to optimize performance and minimise technical risks, targeting efficiency, reliability, and operability [36, 37].

Type Innovation action (pilot)

Partners Leader: TU Darmstadt (DE)
Lime: Lhoist



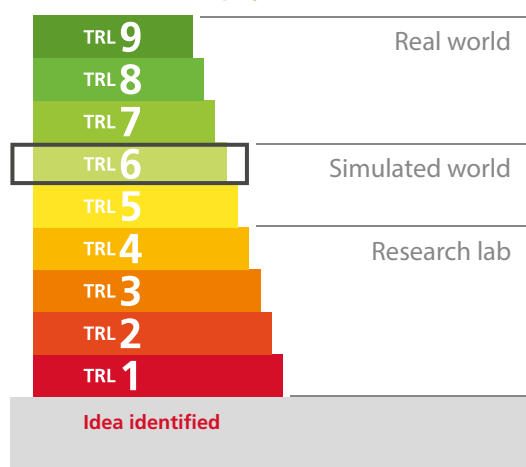
Funding EU / FP7
Total project: 7.3 Mill EUR
EU contribution: 4.7 Mill EUR



Duration 04.2014 – 03.2017

TRL Technology Readiness Level:
TRL 6

Commercial deployment



Contribution to

Carbon looping – Lime technology – CCU.

REFERENCES:

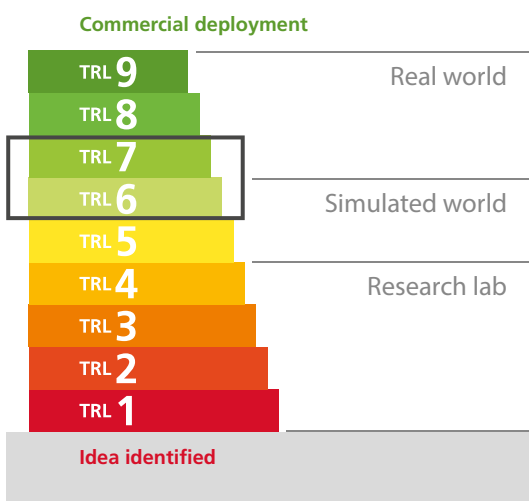
- [36] Stroh A., Alobaid F., Ströhle J., Hasenzahl M.T., Hilz J., Eppe B., 2015. Comparison of three different CFD methods for dense fluidized beds and validation by a cold-flow experiment. Particuology 2015, Article in Press.
- [37] Zeneli M., Nikolopoulos A., Nikolopoulos N., Grammelis P., Kakaras E., 2015. Application of an advanced coupled EMMS-TFM model to a pilot scale CFB carbonator, Chemical Engineering Science: 138, Pp. 482-498.

CSM

Carbon Storage by Mineralisation

ccspfinalreport.fi/print

Type	Innovation action (demonstration)
Partners	Leader: Cluster for Energy & Environment CLEEN (FI) + 18 industry, 9 research (FI) Lime: Nordkalk 
Funding	National Finnish Funding Agency for Technology & Innovation (TEKES) Total project: 15 Mill EUR
Duration	2011 – 2016
TRL	Technology Readiness Level: TRL 6-7



- Use of serpentinite as a CO₂ capturing mineral looked promising, but replicating to limestone minerals technical difficulties and the results were quite poor [39, 40].

Contribution to

Carbon dioxide storage by mineralisation (CSM) – Lime kiln – Process emissions – Multiple policy objectives.

REFERENCES:

- [38] Romao I., Eriksson M., Nduagu E., Fagerlund J., Gando-Ferreira L.M., Zevenhoven R., 2012. Carbon Dioxide storage by mineralisation applied to a lime kiln. 25th International Conference on Efficiency, Cost, Optimisation, Simulation and Environmental impact on Energy Systems. 26-29 June in Perugia, Italy. Pp. 13.
- [39] Teri S. Et al. 2013. CCSP Carbon Capture and Storage Program. Mid-term report. Pp. 82.
- [40] CCSP Carbon Capture and Storage Program 1.1.2011 – 31.10.2016. Final report. Pp. 1-248. ccsp-finalreport.fi/reports/CCSP_Final_report.pdf.

Scope of work

The stepwise carbonation of serpentinite, a rock composed mainly of magnesium silicate mineral serpentinite reacts with the CO₂ to form a stable compound, thus fixing the CO₂ permanently. The reaction kinetics have received attention but the work done in Carbon Capture Storage Program (CCSP) is unique in having the minimization of energy input and chemicals use as starting point. The purpose of Carbon Storage by Mineralisation (CSM) is to promote CO₂ fixation by metal oxides into thermodynamically stable carbonates while benefiting of the exothermicity of the carbonation reaction. Application of the mineral carbonation process at an industrial lime kiln was investigated in a pilot plant as part of the CCSP in Finland.

Status of the project

Project finalized in 2016. The following achievements can be reported:

- The recent study shows that operating at 80 bar carbonation pressure with ~22%-vol CO₂ flue gas without capture, mineral sequestration may be accomplished at an energy penalty of 0.9 GJ/t CO₂ electricity besides 2.6 GJ/tCO₂ heat which can be extracted from the kiln gas [38].
- Direct mineralisation of flue gas instead of separated and compressed CO₂, eliminates the need of expensive and energy intensive processes to isolate and compress CO₂, thus significantly lowering the materials and energy requirements for the overall CCS process chain [38, 40].
- An exergy analysis is used to optimise process layout and energy efficiency, and at the same time maximise the amount of CO₂ that can be bound to MgCO₃ given the amount of waste heat available from the lime kiln.
- Also, experimental results are reported for producing Mg(OH)₂ (and Fe,Ca(OH)₂) from local rock material.
- Operating without CO₂ separation makes CSM an attractive and cost-competitive option when compared to conventional CCS involving underground storage of CO₂ [40].

CO₂LOOP 4 ENERGY STORAGE ●

Storage of renewable energy by means of innovative oxy fuel process, combining electrolysis with CO₂-loop

Scope of work

In a working day, ~70 MWh electricity/day is used in Germany. The available capacity of renewable energy is around 80 MWh (incl. sun & wind). The long-term objective is to increase to 150 MWh/day to respond to future energy need projections. This capacity is not fully available due: the cost for shutdown of not usable wind energy in 2015 is estimated to be around 1 Bill EUR; volatility of energy demand.

This project aim is to assess the feasibility for Energy storage and use of 100% CO₂ for innovative CCU Process.

Status of the project

The project is in its early stages and in a step wise approach will address:

- First step: Use of renewable energy to operate electrolysis through the production of O₂ and H₂ is used in a small scale. To run the innovative process in larger capacities an up-scale is necessary.
- Second step: Operation of shaft kiln with fossil fuels or methane out of oxy fuel process. CO₂-stripping is needed for oxy fuel – synthesis as well as the assessment of the CO₂ – loop. The entire CO₂ is concentrated in the loop of CO₂ => pure CO₂ in the exhaust gas. And the use of CO₂ as coolant of the solids in process
- Potential for optimization of CCU-Process is identified. CO₂ from the shaft-kiln process (e.g. lime-production) is used to synthesize methane with the hydrogen from the electrolysis.
- Support is needed for development/testing of the process. Scale up of hydrogen electrolysis / recuperator / test of CO₂-loop in shaft kiln and optimization of the entire process chain.

Contribution to

Storage of volatile renewable energy as synthesized methane in natural gas stores reduction of cost for shut down of wind energy.

Type Innovation action
(new plant / new process
/ technology validation)

Partners Leader/Lime: Fels (DE)
(partners are evaluated)

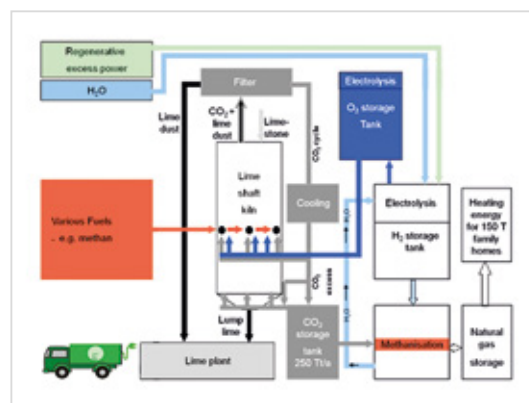
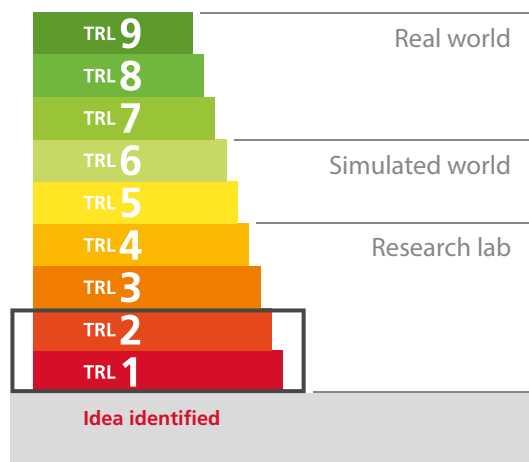
Fels

Funding Required financial support:
~40 Mill EUR

Duration to start during 2018

TRL Technology Readiness Level:
TRL 1-2

Commercial deployment

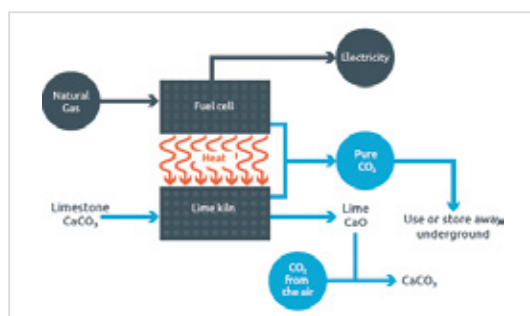
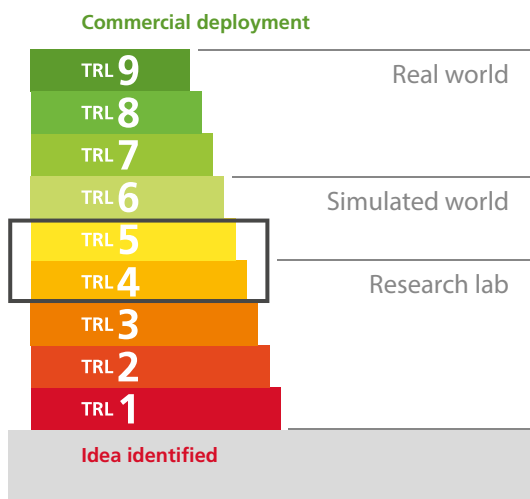


Oxyfuel process with CO₂ loop.

NECAPOGEN 4LIME ●

NEgative-CAarbon emission POWER GENeration from integrated solid-oxide fuel cell and lime calciner

Type	Innovation action (pilot)
Partners	Leader: Origen Power (UK) & Arcola Energy (UK) Lime: Singleton Birch (UK)
Funding	1 Mill £ 
Duration	08.2018 – 08.2021
TRL	Technology Readiness Level: TRL 4-5



The process integrating the solid oxide fuel cell and lime calciner.

REFERENCES:

- [41] Hanak D., Jenkins B., Kruger T., Manovic V., 2017. High-efficiency negative-carbon emission power generation from integrated solid-oxide fuel cell and calciner. Applied Energy 205. Pp. 1189-1201.
- [42] £1M for Greenhouse Gas Removal tech. Innovators Magazine. 22 March 2018.

Scope of work ●

The Paris Agreement is the global commitment to limit by 1.5 to 2°C temperature increase above pre-industrial levels. In addition to low carbon processes, there is also a requirement for negative emissions technologies which can remove 7 gigatonnes of CO₂ from the atmosphere. Energy intensive sectors are under pressure to find ways to meet this societal challenge. Origen Power's 'negative emissions technology' supplies natural gas to a solid oxide fuel cell. About half the chemical energy is converted into electricity and the remainder into high-grade heat which is used to thermally decompose limestone (CaCO₃) in a calciner to produce) lime (CaO) and carbon dioxide. The system is configured so that all the CO₂ generated is pure, making it cheap and easy to either use or store. The lime that is produced can be used in a range of industrial processes and, in being used, removes carbon dioxide from the air.

Status of the project ●

Advanced modelling has shown the technical and economic viability of the technology [41]. A detailed techno-economic assessment of the process [42] indicates that if the electricity and the lime are sold at wholesale market prices, then the costs are covered without a carbon price – even as it removes carbon dioxide from the air. A bench scale demonstrator has been built by Cranfield University and the UK Government Energy Entrepreneurs fund has awarded a grant to build a 400 kW prototype at the Singleton Birch facilities in UK.

Contribution to ●

Negative emissions technologies (NETs) – Greenhouse gas removal (GGR) – Net zero emissions – Paris agreement.

4. Improvement in Energy Efficiency

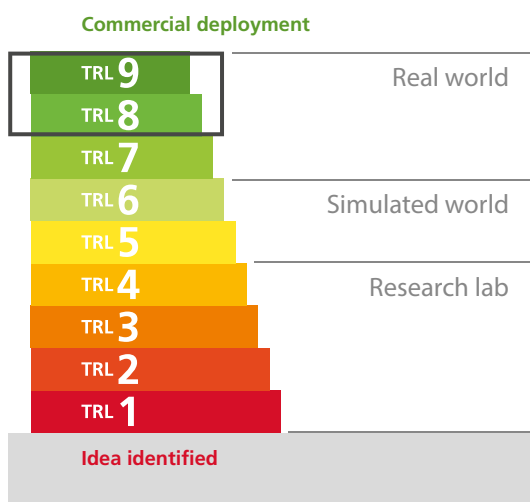
- ADiREN4Lime
- EcoLOOP
- WHeatRec4PG
- Energy optimisation
- Energy generation
- CHP Generation
- Other company projects/initiatives



ADIREN4LIME • Anaerobic Digestion as a Renewable Energy for the Lime Industry

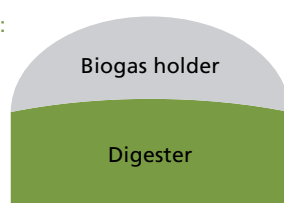
birchenergy.co.uk

Type	Innovation action (new plant)
Partners	Leader: Birch Energy (UK) Partner: Singleton Birch (UK)  
Funding	Own initiative + UK Total project: 8.5 Mill £ UK contribution: yes
Duration	11.2014 – 04.2015
TRL	Technology Readiness Level: TRL 8-9



Biomass feedstock:

- Manures.
- Energy crops.
- Food waste.
- Agriculture by products.
- Biosolids.



Biomass feedstock and stirred tank.



AD installation.

Scope of work

Lime processing needs large amount of energy (kiln, hydrator, crushers, mill). Objective:

- Reduce energy costs and reliance on grid electricity and gas.
- Invest in gas or electricity generating projects.
- 2013 decision made to build an Anaerobic Digester (AD) to meet these objectives.
- AD is a process where micro-organisms break down some organic biomass in anaerobic conditions to produce biogas, $\text{CH}_4 + \text{CO}_2$.
- The methane can be used to produce electricity or upgraded to Biomethane for injection into the gas grid and can be used as a fuel for lime kilns.

Status of the project

Project finalized in 2015. Birch Energy financed, managed, operates the AD installation in a restored area of the former quarry operations. The following achievements can be reported:

- Built in 2 phases: 1: 1.25MW Combined Heat and Power (CHP); Phase 2: 2 MW CHP plus 1.5 MW drier.
- Uses 45,000 tonnes of feedstock annually.
- Combined output of the 3 AD plants is 110% of Singleton Birch's electricity demand.
- Grid connection with capacity to export 100% of electricity to grid and generates 15,000 GWhrs of electricity per annum.
- Dryer using waste heat from the CHP engines to dry digestate as a high value fertiliser [43].
- Employs 5 people.

Contribution to

Energy efficiency – Renewable energy into the grid – Agriculture – Fertilizer – Waste management – Management – Employment.

REFERENCES:

[43] Haworth M. 2016. Anaerobic Digestion as a renewable power source for the Global Lime Industry. ILA October 2016 annual meeting in Washington (USA).

Scope of work

Lime processing needs large amount of energy (crushers, kiln, mill, hydrator). The objective of the ecoloop project is to assess the generation of gas from synthetic waste (syngas) as an energy surplus. This energy related project, apart the reduction of energy cost and dependency also provides environmental benefits such as reduction of residual waste thanks to waste to energy transformation. This approach was tested in one German site.

Status of the project

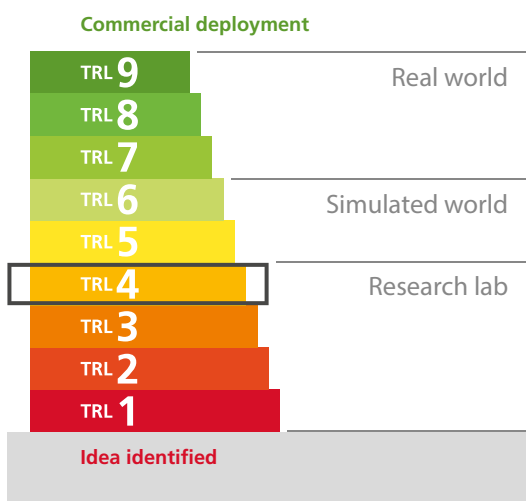
Fels is overlooking the trial for the ecoloop installation at an industrial facility. The following achievements can be reported:

- Ecoloop achieves a higher thermal efficiency compared with other processes, meaning that energy can be generated from a lower volume of residual waste, resulting in CO₂ Emission reduction.
- Use of syngas results in significant lower production cost compared to fossil fuels.
- Waste disposal costs are reduced since Ecoloop transforms waste to energy as the most cost-efficient option.
- For specific applications, by-product recovery such as metals and phosphor is also possible.
- Ecoloop process is environmentally friendly since: 1. The lime serves as "chlorine sink" for the chlorine found in residual waste. 2. The formation of dioxins and furans is prevented since no combustion takes place at the reactor but only gasification, making flue gas scrubbing unnecessary.
- Ecoloop environmentally friendly nature is recognized through two awards it has received: 1. German Innovation Prize for Climate and the Environment (IKU) and 2. Hugo Junkers Innovation Prize.
- The Ecoloop 32 MWatt pilot plant is located at the Kaltes Tal site and is currently at commissioning stage [44].

Contribution to

Energy efficiency – Waste to energy – Plastic waste management – Plastic waste.

Type	Innovation action (pilot)
Partners	Leader: Ecoloop (DE) Lime: Fels (DE)  
Funding	Own initiative + DE funds (EUR) Total project: not reported DE contribution: not reported
Duration	2015 – ongoing
TRL	Technology Readiness Level: TRL 4



Supply and return bucket elevator for the lime circuit and RDF delivery.

REFERENCES:

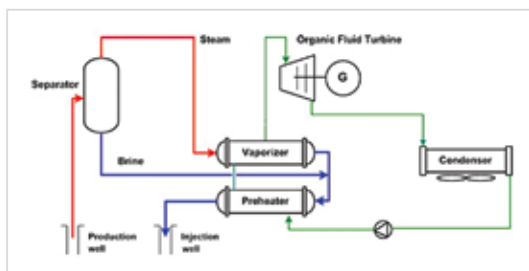
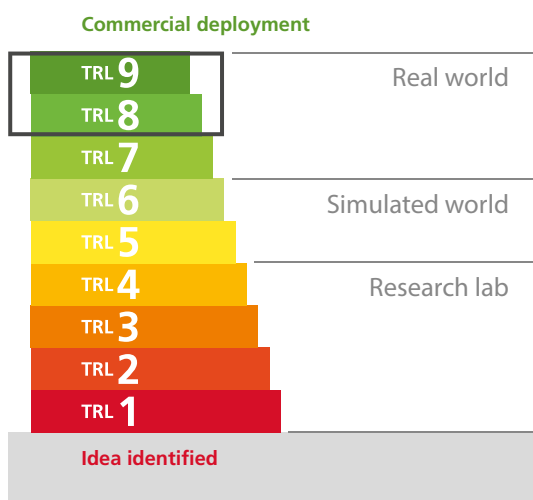
[44] 2014. Xella: Sustainability report 2014. Ecoloop project. Pp. 33, 48, 64.

WHEATREC4PG ●

Waste Heat Recovery for Power Generation

theenergyst.com/wp-content/uploads/2016/05/theenergyst_0516-web.pdf

Type	Innovation action (pilot)
Partners	Leader/Lime: Lhoist/Steetley (UK)  
Funding	Funding: Own initiative + UK support Total project: 1.3 Mill £ UK support: 200 K £
Duration	06.2012 – 09.2013
TRL	Technology Readiness Level: TRL 8-9



Organic rankine cycle (ORC).

Contribution to

Energy efficiency – Waste heat recovery – CO₂ mitigation – Power generation.

REFERENCES:

- [45] Bryant D. 2016. Waste not, Want Not. ENERGYST. Pp. 48-49.
[46] 2013. Heatcatcher secures waste heat recovery project with Steetley Dolomite. Global Cement: Pp. 20.

Scope of work

Lime processing needs large amount of energy for the different multiple processing stages. The objective of energy intensive industry operators is to improve the overall energy efficiency, resulting in reducing the energy costs and the reliance on grid electricity. This are the drivers for the feasibility study of a Heat recovery system installation in lime operations:

- Waste heat recovery systems integrate organic rankine cycle (ORC) technology into renewable heat sources, industrial kilns and furnaces.
- The ERC generator can convert waste heat temperatures as low as 85°C into electricity.
- Waste heat from heat intensive industrial processes can be recovered by: 1. High temperature hot water above 85°C. 2. Saturated steam above 6 bar. 3. Exhaust gas above 130°C.
- These sources of waste heat are fitted with a heat exchanger designed for the application.

Status of the project

Project is already operational. The following can be reported:

- A waste heat to power system was commissioned in September 2013 at Lhoist-Steetley Dolomite facility in Thrislington-UK.
- The WHRPG system recovers 4 MW of thermal power from a rotary kiln exhaust gas, and converts it to 0.5 MWe of low carbon electrical power.
- The new system delivered 25% improvement in electrical efficiency of the plant.
- it can generate net power of around 3,000 MWh annually, equivalent to 7,500 hours of carbon-free electricity.
- In total, kiln CO₂ emissions will be reduced by 1,600 tonnes per year.
- The project offers an attractive return on investment, when considering £1.3m investment against purchasing 3,000 MWh per year of electricity from the grid over the next 10 years [45, 46].

ENERGY OPTIMISATION ●

Reduced energy consumption through optimized processes and capacity use

www.spin-project.eu/downloads/2_SPIN_Project_biogas_barrierefrei_reduziert.pdf

Scope of work

Lime processing needs large amount of energy (kiln, hydrator, crushers, mill). Objective:

- Improve energy efficiency and introduce renewable fuels.
- Reducing energy consumption, a priority in new investments and repairs in the lime processing facilities.

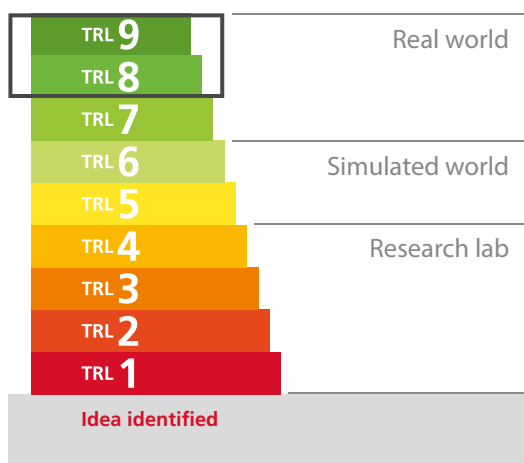
Status of the project

Few projects were implemented, and the following can be reported:

- The automation system of the lime kiln in Pargas was renewed in 2016; the new automatic optimization system adjusts the kiln's operation parameters for obtaining uniform lime quality and low energy consumption. The system monitors constantly the measurements of the process and product quality to level out changes in the process. It also decreases the possibility for production interruptions. The automatic process optimization has been calculated to save annually up to 4000 MWh heat energy [47].
- The grinding plant in Vampula uses biogas supplied through a 1.5 km pipeline by the local biogas producer Vambio. The gas is produced from by-products of the food industry, slaughterhouses and livestock-breeding as well as wastewater sludge [47].
- In 2015, Nordkalk tested the use of bio-fuel in Ignaberga (Sweden) facility. The fuel is a surplus product from ecological feed production. The tests have given good results, and so in 2016, Nordkalk invested in equipment to adjust the production and equipment for the switch from fossil fuels to biofuels. The stone drying in Ignaberga runs now 100% on biofuel. Nordkalk was granted climate investment support for the Ignaberga project by the Swedish Environmental Protection Agency in December 2015. Nordkalk is one of twelve companies receiving support for "measures that demonstrate the greatest sustained reduction of greenhouse gas emissions per crown invested" [47, 48].

Type	Innovation action
Partners	Leader/Lime: Nordkalk (FI, SE) ◆ Nordkalk
Funding	Own initiative + Swedish Swedish contribution: yes
Duration	2011 – 2016
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



Biofuel tested at Ignaberga in Sweden.

Contribution to

Energy efficiency – Renewable fuels.

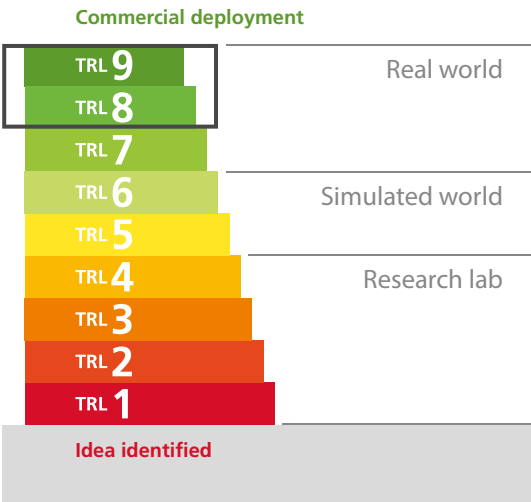
REFERENCES:

- [47] 2011. Nordkalk. Environmental report. Pp. 12.
[48] Reinson K. & Roioiose Antti. 2012. BioGas. Report prepared by University of Taru. Pp. 11.

ENERGY GENERATION ●

Largest Solar panel farm in Wallonia by a mining company

Type	Innovative action (renewable energy generation)
Partners	Leader/ Lime: Carmeuse (BE) 
Funding	Own initiative + Wallonia Total project: not reported Wallonia contribution: yes
Duration	2014 – 2017
TRL	Technology Readiness Level: TRL 8-9



Solar panel farm at Moha (Wallonia).

Scope of work ●

Limestone processing to make, quicklime & hydrated lime needs large amount of energy (crushers, kiln, hydrator, mill). Objective of this project is multifold:

- Invest in renewable energy generating project.
- Generate renewable energy to be used for the lime operating facilities.
- Improve the energy mix of the lime manufacturing.
- Reducing the overall energy consumption, a priority in new investments and repairs in the lime processing facilities.

Status of the project ●

These objectives were addressed by building a photovoltaic farm near the lime facilities. The following can be reported:

- The largest Photovoltaic farm in Wallonia to date. 13.200 solar panels will supply annually over 3,6 GWh of electricity to the Carmeuse quarry located at Moha (province of Liège).
- On an annual basis, the solar plant will cover 9% of the quarry's and process facility total electricity consumption. PV coverage will average over 14% during the months of April till September.
- The ground-mounted panel arrays are installed on 4,5 ha of industrial wasteland right next to the quarry and they are operational since 2017.

Contribution to ●

Renewable energy production – Lower CO₂ emissions.

CHP GENERATION ●

Combined Heat and Power (CHP) for Limestone Milling

Scope of work

Installation of a combined heat and power plant (CHP).

Producing electrical power with two micro gas turbines and usage of waste gas from gas turbines for drying purposes in limestone milling:

- Energy recovery from drying / heating off gases: Instead using 40% of natural gas' thermal energy for producing electrical power, in the CHP more than 70% of thermal energy is utilized.
- Contribution to electrical power supply.
- Backup electrical power supply for community.
- Reduce energy costs and reliance on grid electricity and gas.

Status of the project

Project realized in 2012 with commissioning in 2013.

Few projects were implemented, and the following can be reported:

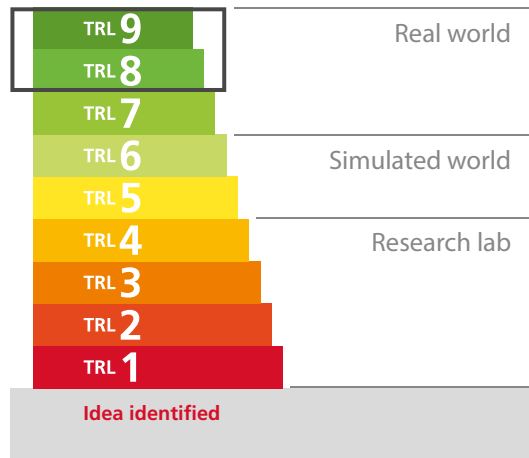
- The micro gas turbines had been implemented in 2013 in plant Middel [D] and were in operation since that time.
- The waste gas of the turbines contains of 790 kW thermal power. A small increase of approx 30 kW is required by an additional gas burner is required to lift the energy content of the waste gas to the required level. The connected vertical roller mill dries the product on full production rate.
- The limestone feed material has a humidity of 7-8% and is dried to < 1% in the finished product.
- Installation costs ~600 k€.

Contribution to

Energy efficiency – Off heat utilisation.

Type	Innovation action (demonstration)
Partners	Leader/Lime: Lhoist (DE) 
Funding	Own initiative Total project: not reported
Duration	2012 – 2013
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



Process Innovation

• Heat recovery in single shaft kilns

Energy losses induced by the off gas temperature exiting Lime kilns. To tackle some of these losses, Maerz-Ofenbau AG has developed a process incorporating heat exchangers as described in patent EP1148311 81 "Process for firing a material containing carbonates". According to the patent, part of the "combustion air to be supplied by means of the burning lances is heated within the preheating zone by being passed through heat exchange tubes which are positioned parallel to the shaft wall, distributed over the kiln cross-section and suspended in the preheating area of the kiln". Fels-Werke in Germany currently installs a different device but the principle is the same.

• Biomass in PFR kilns

Process innovation is emerging with PFR kilns, which are capable of combusting biomass rather than fossil fuels. Some 14 PFR kilns, two (captive) rotary kilns and one projected (captive) rotary kiln are known to be reengineered or newly built where finely ground wood is in use. Two more kilns are fuelled with cork. For the time being, wood and even contaminated wood is thought to be the easiest to handle and combust, but investigations also target olive stones; coconut cores, sugar cane, jatropha nuts and rice hull.

• Lean gas in PFR kilns

PFR kilns are normally designed to combust natural gas with net calorific values around 48 MJ/Nm³. Coke oven gas (16-35 MJ/Nm³) is also in use where Lime installations operate adjacent to steel mills. Current research focuses on reengineering the gaseous flows in a PFR kiln and make it capable to utilize lean gases which come with net calorific values of 7,5 MJ/Nm³ and less. The research has originally been triggered since existing sources

like converter gas (8-12 MJ/Nm³) and/or blast furnace gas (4-6 MJ/Nm³) are available. Maerz-Ofenbau AG has accompanied a Chinese steel manufacturer who successfully operates a 500 tpd PFR kiln with lean gas of less than 5 MJ/Nm³.

Such lean gases also originate from installations producing biogas, sewage gas, landfill gas, etc. In future it might be an attractive symbiosis to combine a biogas plant dedicated to the supply of lean gas to a Lime plant.

• Oxy fuel combustion in PFR kilns

Off gases of Lime kilns normally contain CO₂ in the order of shortly less than 20% to shortly above 40% (by dry volume). The concentration is basically a function of fuel in use and amount of air intake. The lowest concentrations result from burning natural gas while the highest occur from burning coke.

In 2010 Messer Group was granted a patent "Verfahren und Vorrichtung zur Kalkherstellung" (publication number: EP 2 230 223 A1), followed by a patent granted to Maerz-Ofenbau AG in 2012 "Device and method for combusting and/or calcining fragmented material" (publication number: WO2012/072332). Both patents target the combustion of oxygen rather than air in Lime kilns. Similar to theoretical projects in other industries, this will enlarge the CO₂ concentration and thus ease a potential CO₂ stripping from the off-gases. These reflections are at a very early stage of development. Oxy fuel combustion substantially increases the temperature of the kiln atmosphere, which will be harmful to Lime, as sintering immediately will occur. Other industries tackle the issue by recycling part of the off gas into the combustion chamber and use it as a cooling agent. This is also possible in a Lime kiln but needs far more engineering and process control. The recycled gas flow may not get in contact with the Lime. If so, immediate recarbonation will take place and the Lime quality will be diluted.

5. Innovation in Use Phase

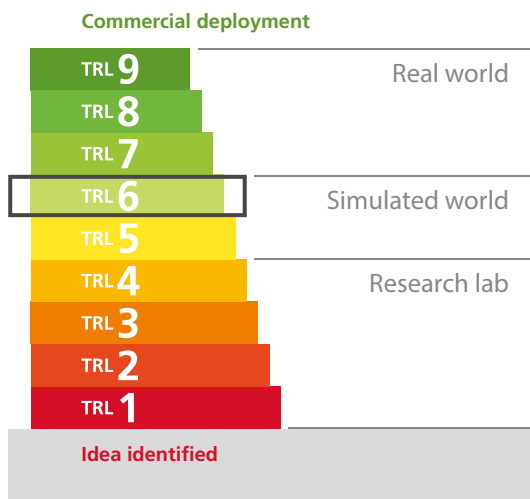
- Steel: ULCOS
- Steel: LIMEFLOW Steel
- Construction materials (Mortar): ECO-SEE
- Construction materials (Mortar): ISOBIO
- Construction materials (Mortar): Compact mortar pellets
- Construction materials (Mortar): Hempcrete
- Civil Engineering: HMA LCA study
- Environmental protection (FGT): Lime pellets for marine SOx reduction
- Environmental protection (FGT): Lime in FGT and WTE
- Environmental protection: Cleaner Port (Renere Havn)
- Environmental protection: Harbour Sludge Stabilisation
- Agriculture: P runoff avoidance
- Agriculture: Lime in AGRI 1
- Agriculture: Lime in AGRI 2
- Agriculture: Soil-water use efficiency
- Glass: Lime in Glass making



ULCOS • Ultra-Low CO₂ Steel Making

cordis.europa.eu/project/rcn/80229_en

Type	Innovation action (pilot)
Partners	Leader: Arcelor Mittal (FR) & 47 partners (15 EU countries) Lime: Lhoist  
Funding	EU / FP6 Total project: 35.3 Mill EUR EU contribution: 20 Mill EUR  
Duration	09.2004 – 08.2010
TRL	Technology Readiness Level: TRL 6



Contribution to 
CCU – CCS – Lime technology – Low CO₂ steel-making.

REFERENCES:

[49] Van der Stel J., 2013. Development of the ULCOS-Blast Furnace: Working towards technology demonstration. The ULCOS-BF developments in Europe. IEAGHG/ IETS Iron and Steel Industry CCUS and Process Integration Workshop. 4-7 November 2013 in Tokyo, Japan.

Scope of work

ULCOS is a major RTD program, which plans to find innovative and breakthrough solutions to decrease the CO₂ emissions of the Steel industry. The target is reduction of specific CO₂ emissions of 50% as compared to a modern Blast Furnace. The project aims to deliver a concept process route, based on iron ore, with a verification of its feasibility in terms of technology, economic projections and social acceptability. The project hence starts by assessing a panel of technologies, which have passed a first prescreening but need to be investigated further. This approach is believed to be the most efficient in terms of resources and lead-time necessary to develop the new technology.

Status of the project

Project finalized in 2010. The following achievements can be reported [49]: ULCOS has tested four process concepts that could lead to a reduction of Carbon dioxide (CO₂) emissions by more than half compared to current best practice. The four breakthrough technologies identified are:

- Top Gas Recycling Blast Furnace with CO₂ Capture and Storage (CCS): this removes the CO₂ and recycles the carbon monoxide (CO) back into the blast furnace, potentially using less than half the emissions of today's state-of-the-art blast furnaces. ULCOS has already successfully pilot tested top gas recycling at an experimental blast furnace that produces 35 tonnes of steel per day in Lulea, Sweden.
- Hlsarna with CCS: this processes iron ore almost directly into steel, thus skipping the manufacturing of pig iron pellets. More energy-efficient than traditional steelmaking processes, it could reduce the carbon footprint by up to 20%.
- ULCORED with CCS: producing direct-reduced iron (DRI) from iron ore with a reducing gas [49].
- Electrolysis: already used in industrial nickel, aluminium and zinc production. It could eventually replace the blast furnace altogether by passing an electric charge through an alkaline solution to separate the iron from iron ore.

LIMEFLOW STEEL

Lime Injection & Flowability in Steel Making

astm.org/DIGITAL_LIBRARY/STP/PAGES/STP104319

Scope of work

Steel is one of the main markets where lime is used. The challenge of the market is to improve the flowability of the lime injection during the steelmaking. Project objectives were to improve the flowability of lime as well as the handling system delivering better performance and efficiency during the steel making.

Status of the project

Project finalized in 2008. Key deliverables of this project address the technology development and innovation aspects:

- Multiple point injectors located close to the slag allows lime dispersion into the slag/metal interface.
- Since 100% of lime is managed by pneumatic injection, the lime flow management is easier [50].
- Small particles of quality dolomitic lime and high calcium lime delivered into the molten slag/metal interface using injection technology.
- These particles quickly dissolve providing the steelmaker very responsive control of slag chemistry.
- Due to automatization, the control of lime additions compared to other methods of lime additions is easier.
- Reduced cost related to maintenance compared to mechanical handling systems [51].
- 10% reduced lime loss, due to baghouse and lower disposal.
- Cleaner environment and improved safety for workers is also achieved [52].
- This technology developed in the USA is also being used extensively in the EU steel making sector [53].

Contribution to

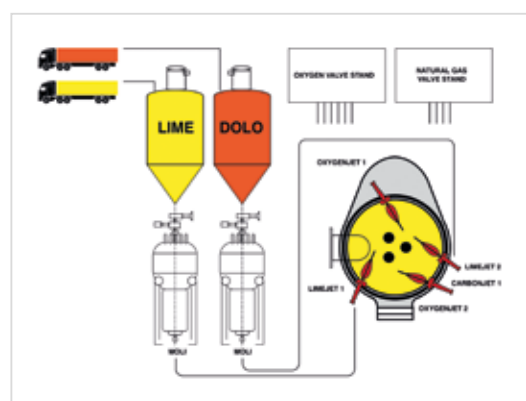
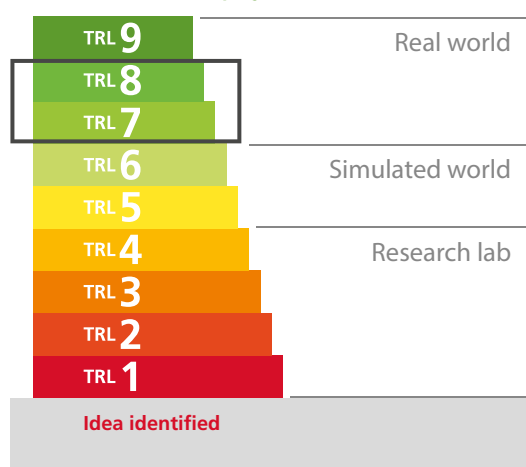
Steel technology – Resource use optimization
– Improved H&S – Multiple policy objectives.

REFERENCES:

- [50] Iacuzzi M., Marcuzzi S., Tolazzi D., Candusso C., 2008. New developments and operational results in the use of fixed side-wall injectors in the electric arc furnace, Scanmet III, June 2008.
- [51] Wolfe L., Massin J.P., Hunturk T., Ripamonti J.P., 2008. Lime injection technology – a viable tool for the

Type	Innovation action (process)
Partners	Leader/ Lime: Carmeuse (BE) 
Funding	Own company initiative Total project: not reported
Duration	2004 – 2006
TRL	Technology Readiness Level: TRL 7-8

Commercial deployment



The lime injection scheme.

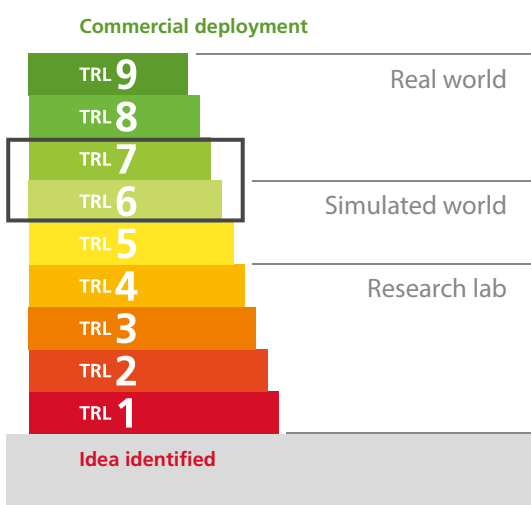
- electric arc furnace. SCANMET III: 3rd International Conference on Process Development and Iron in Steelmaking. 8-11 June at Lulea (Sweden). Platform presentation.
- [52] 2016. New developments and operational results in the use of fixed side-wall injectors in the Electric Arc Furnaces 47th International SteelMaking seminar. 27-29 September 2016 in Rio De Janeiro, Brazil. Platform Presentation. [more-oxy.com/news/fee384cc516bacc2104ca442c1b0bb8fcdca80b/47th-international-steelmaking-seminar-brazil.html?cat=news&year=2016](https://www.more-oxy.com/news/fee384cc516bacc2104ca442c1b0bb8fcdca80b/47th-international-steelmaking-seminar-brazil.html?cat=news&year=2016).
- [53] D. Wolfe L.D. 2007. Overview of lime injection in the electric arc furnace.

ECO-SEE

Eco-innovative, Safe and Energy Efficient wall panels and materials for a health-ier indoor environment

eco-see.eu

Type	Innovation action (pilot)
Partners	Leader: Bath University (UK) Lime: BCB Lhoist Group
	
Funding	EU / FP7 Total project: 9.4 Mill EUR EU contribution: 6.5 Mill EUR
Duration	09.2013 – 08.2017
TRL	Technology Readiness Level: TRL 6-7



Contribution to

CCU/CCS – Mortar – Eco material – Healthier indoor environment – Multiple policy objectives.

REFERENCES:

- [54] Nuño M., Ball R.J., Bowen C.R., 2016. Photocatalytic Properties of Commercially Available TiO₂ Powders for Pollution Control. InTech Semiconductor Photocatalysis – Materials, Mechanisms and Applications 2016. Chapter 22. Pp. 613-633. dx.doi.org/10.5772/62894.
- [55] Tobaldi D.M., Pullar R.C., Seabra M.P., Labrincha J.A., 2014. Fully Quantitative X-ray characterization of Evonic aerioxide TiO₂ P25 ®. Materials Letters, Volume 122. 1 May 2014. Pp. 345-347. doi:10.1016/j.matlet.2014.02.055.

Scope of work

The project aims to:

- Use natural eco-materials for healthier indoor environments through hygrothermal (heat and moisture) regulation and the removal of airborne contaminants through both chemical capture and photocatalysis.
- Advancing state of the art in the technology and application of multifunctional bio-based insulation materials, vapour permeable and hygrothermal and moisture buffering finishes, together with wood panel and lime products, to create both internal partition and external highly insulated wall panels.
- Novel chemical treatments and processes will be used to enhance volatile organic compound capture capacity of materials.
- Development of highly novel photocatalytic coatings using nanoparticle technology, which will be suitable for use in interior spaces and compatible with lime and wooden surface materials.

Status of the project

Project ongoing until 2017. The following progress can be reported:

- Successfully developed to demonstration stage a range of innovative construction materials to improve comfort.
- Innovative materials include: photocatalytic treated wood panel and lime plaster systems. clay and lime based plasters with enhanced moisture buffering properties.
- A range of designs for external (insulating) and internal wall panels have also been produced. Combined these innovative products will deliver solutions with significantly reduced embodied energy and through design achieve longer life at lower build cost.
- Techno-economic analysis, and Life Cycle (Cost) Analysis will be conducted as well to assess environmental benefits and costs [54, 55].

ISOBIO

Natural High Performance Insulation

isobioproject.com

Scope of work

The ISOBIO project aims to develop a new approach to insulating materials through the novel combination of existing bio-derived aggregates (i.e. straw, clay, wheat or grasses) with low embodied carbon with innovative binders to produce durable composite construction materials with:

- Lower embodied energy and carbon 50% compared with traditional oil based insulation panels.
- Increase thermal insulation compared with traditional systems by at least 20%.
- Reduce costs by at least 15% over traditional systems, thanks to the vertical integration from raw material production through to finished systems.

Status of the project

Project ongoing until 2019. The following progress can be reported:

- The new materials improve upon the performance of conventional materials, they also offer new features. Hemp shiv, which is the core of the hemp stalk, for example, has a porous structure that provides moisture buffering to maintain humidity at a more constant level.
- The ISOBIO materials take advantage of the natural moisture sorption/desorption characteristics of bio-based materials, which is known to passively manage the indoor environment resulting in improved indoor air and environmental quality, whilst at the same time reducing the demand for air conditioning.
- As part of its life cycle analysis, the project is analysing over 100 existing materials.
- On the supply side, sourcing local organic materials helps reduce transportation costs, while using waste or byproducts as inputs helps control the cost of the final product [56].

Contribution to

CCU/CCS – Mortar – Eco material – Better insulation performance.

Type Innovation action (pilot)

Partners

Leader: TWI (UK)

Lime: BCB Lhoist Group



Funding

EU / H2020

Total project: 6.3 Mill EUR

EU contribution: 5.5 Mill EUR



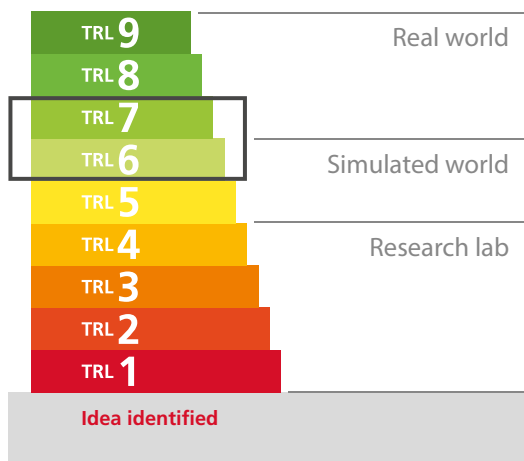
Duration

02.2015 – 01.2019

TRL

Technology Readiness Level:
TRL 6-7

Commercial deployment



Schematic view of the project upscale stages.

REFERENCES:

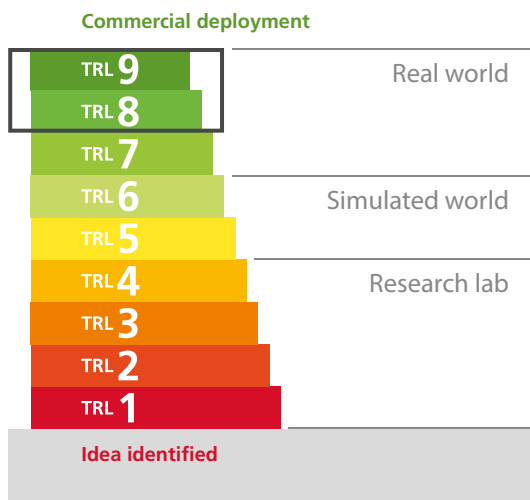
[56] 2014. Le béton de chanvre gagne en performances. lemoniteur.fr/article/le-beton-de-chanvre-gagne-en-performances-32129630.

COMPACT MORTAR PELLETS ●

Dust-free building site using Compact mortar pellets

youtu.be/Q3WfMngEcDw

Type	Innovation action (product)
Partners	Leader/Lime: Fels (DE) Fels
Funding	Company own initiative Total project: not reported EU contribution: not applicable
Duration	02.2015 – 08.2017
TRL	Technology Readiness Level: TRL 8-9



The preparation of traditional mortar (first photo) versus compact mortar pellets.

Scope of work ●

In the building sector employers need to reduce workers' exposition to comply with Occupational Exposure Limits (OEL). In Germany, these are set by TRGS 900 (Technical rule hazardous substances) and have been made more restrictive for dust exposure in 2014. The limit for alveolar dust – previously was 3 mg/m³ – now it is 1.25 mg/m³:

- In building industry, only 50% of all measurements comply with < 2.0 mg/m³. This applies for Germany, according to "Justification of new general dust limit in TRGS 900", Ausschuss für Gefahrstoffe 2014.
- Transitory period until 2018 unless no suitable products are available.

Status of the project ●

To address this challenge, the research and development is finalized and the product "low-dust compacted mortar pellets" have won and award [57] and will be on the market in summer 2017. The following advantages of the novel product can be reported:

- Pouring the compact mortar in the mixing recipient reduces drastically the dust and minimizes the worker exposure.
- Total self-dissolution time is 90 sec and results in a very homogeneous mixture ready to use.
- Up to 20% more efficient than ordinary mortar.
- New, water-resistant premium packaging, also for outside storage.

Contribution to ●

Mortar – Eco material – Low dust exposure – Occupational hazard management – Product innovation.

REFERENCES:

[57] German Labor Protection Award. 2015. Potential: new technological standard for bagged products. 1st place in category for technical solutions, large companies: Fels-Werke GmbH for "Compacting of dry mineral ready-mixed mortars into pellets". October 2015.

HEMPCRETE ●

Hemp-lime Based Construction Materials – an Ecological, Sustainable and Carbon Negative Solution

carmeuse-construction.com/your-applications/building-materials/hempbuilding

Scope of work

Residential and commercial buildings are the world's biggest energy consumers and CO₂ emitters. In the European Union, the buildings consume about 40% of the Union Energy. More than 50% of the building energy consumption goes for heating/cooling. To make EU buildings energy efficient the focus is to increase the market value of green construction materials. The objective of this project is to illustrate how hemp-lime based construction material can respond to these EU multifaceted policy objectives.

Status of the project

Project was terminated in 2015. Product on the market in Multiple EU countries (BE, NL, RO). Key deliverables of the project consist of:

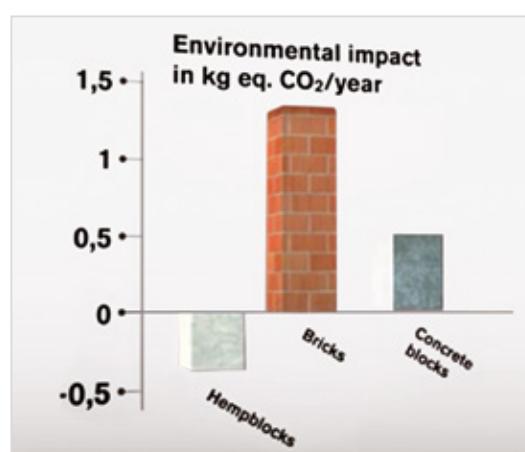
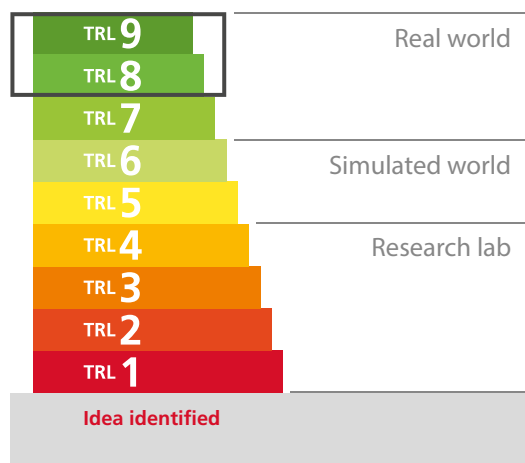
- 100% of the hemp plant can be used in many different applications such as textiles, plastics, food products, papers, oils, paints, building material. The later, accounting for around 60% of the hemp, fibers and shives.
- Grows quickly and locally with one of the highest yielding – 4 to 6 months from seeding till harvest – without need of pesticide chemicals.
- 1 kg of dry hemp stores 0,38 kg of carbon, equivalent to 1,4 kg CO₂.
- Mixing lime with hemp, improves comfort and health thanks to better breathability, no condensation build-up, lower thermal conductivity, antibacterial activity, more flexibility than concrete, which reduces cracks.
- Other benefits.
- Durability: stronger than conventional fibers such as glass and rock fibers since it can be used for inner/outer masonry and/or insulation.
- Carbon sequestration during the growth and Carbon negative footprint & sustainable during use phase in a building [58].

Contribution to

Mortar – Eco material – Carbon capture and storage – Product innovation.

Type	Innovation action (pilot)
Partners	Leader/ Lime: Carmeuse (BE) 
Funding	Own company project Total project: not reported
Duration	2013 – 2015
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



CO₂ footprint of hemp versus bricks concrete.

REFERENCES:

[58] Van Rompay G., 2015. Hemp-lime Based Construction Materials – An Ecological, Sustainable and Carbon Negative solution. ILA Conference. 8 October 2015 in Istanbul (Turkey).

HMA LCA STUDY ●

Life Cycle Assessment of Hot Mix Asphalt using lime to improve road durability & low carbon footprint

sciencedirect.com/science/article/pii/S1361920916304631

Type	Innovation action (sustainability)
Partners	Leader/Lime: EuLA (EU) 
Funding	Own initiative Total project: not applicable
Duration	2011 – 2015
TRL	Technology Readiness Level: TRL 9

Scope of work ●

The main objectives of this project were:

- Assess 110 publication/reports on the effect of lime in asphalt [59].
- Assess environmental footprint of all the life stages of a Hot Mix Asphalt (HMA) road (raw materials, transport, construction, maintenance, recycling, end of life) by means of life cycle assessment tools.
- Comparative assessment between classical HMA vs Modified HMA.

Status of the project ●

Project finalized in 2015. The following findings can be reported:

- Hydrate increases road durability with 25% based on science and testimonies from users [59].
- For the lifetime of the road, modified HMA has the lowest environmental footprint compared to classical HMA (43% less primary total energy consumption resulting in 23% lower GHG emissions) [60, 61].

Contribution to ●

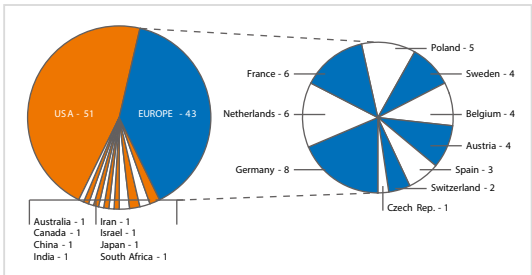
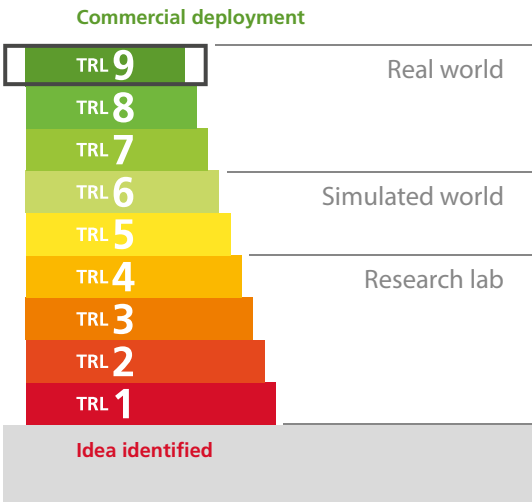
Road durability – Sustainability – Circular economy – Traffic jam avoidance.

REFERENCES:

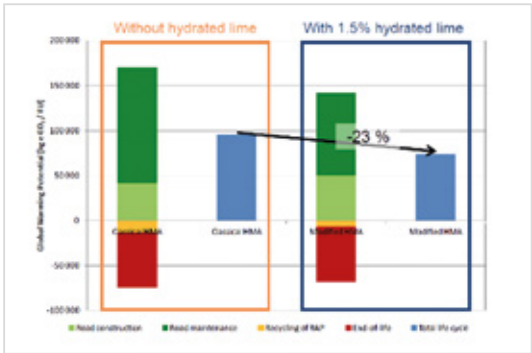
[59] Lesueur D., 2011. Hydrated Lime: A Proven Additive for Durable Asphalt Pavements – Critical Literature Review. EuLA Ed., Brussels. Pp. 1-81.

[60] Schlegel T., Puiatti D., Ritter H.-J., Lesueur D., Denayer C., Shtiza A., 2016. The limits of partial life cycle assessment studies in road construction practices: A case study on the use of hydrated lime in Hot Mix Asphalt. Transportation Research Part D: Transport and Environment. Volume 48. Pp. 141-160.

[61] Ritter H.-J., 2014. Use of Hydrated lime in asphalt in Europe: current state. International Lime Association Meeting. Vancouver, Canada. October 2014. Platform presentation.



Summary of literature review sources [59].



Results from the comparative LCA [60, 61].

LIME PELLETS FOR MARINE SO_x REDUCTION ●

doi.org/10.15480/882.1216

Scope of work ●

55,000 merchant ships annually account for more than 90% of global trade volume: 22 Mill tonnes SO₂ per year. The sulphur emission corresponds to approx. 400 large coal-fired power plants without flue gas treatment.

As from 2015, in the emission control areas (ECA) the allowed sulphur content in marine fuels is reduced down to 0.1%. For the North Sea and the Baltic Sea, this for example, corresponds to 500 thousand tonnes. The current sulphur threshold for global shipping is at 3.5%, but from 2020 on the maximum is reduced down to 0.5%.

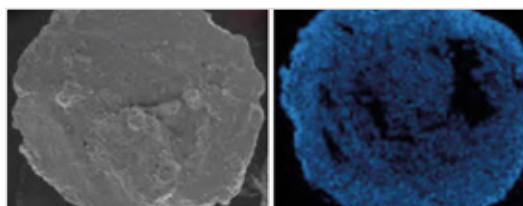
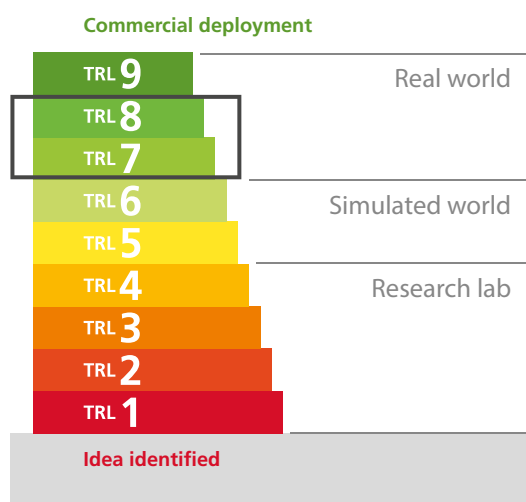
In order to have the opportunity to run vessels with low cost heavy fuel oil, two existing gas cleaning systems are in usage: 1. Dry EGCS (Exhaust Gas Cleaning System) – hydrated lime pellets in a packed bed filter) and 2. Wet ECGS (sodium hydroxide solution).

Status of the project ●

The following results have been proven and can be reported:

- High efficient process and free of waste water and sludge. In contrast to the wet scrubbers, the sulphur is bounded and not released into the hydrosphere. Moreover, this environmentally friendly reacted product, responds to numerous other industries.
- Installation of subsequent catalytic reduction of NO_x is possible without reheating the flue gas. Efficiency of SO₂ removal > 95% reliably achieved in successful large-scale trials on container and bulk vessels in a 12 month continuous operation. The expectations of the shipowners were fulfilled.
- Further usage of cost-effective heavy oil.
- Due to the compact design, a subsequent installation on existing vessels is possible with little effort and cost attractive.
- The Dry EGCS process stands for comparatively low investment and operating costs. The return of investment (RoI) is within 3-4 years.
- Eco-friendly reaction products, oxidation of soot on alkaline pellets.
- No shifting of the pollutants from the atmosphere to the hydrosphere [62, 63].

Type	Innovation action (product)
Partners	Leader/Lime: Fels (DE) Fels
Funding	Own initiative (DE) Total project: not reported
Duration	2011 – 2013
TRL	Technology Readiness Level: TRL 7-8



Sulphur absorption core before (left) and after (right).

Contribution to ●

Environmental protection – Innovative technology – Fuel optimization – Energy efficiency.

REFERENCES:

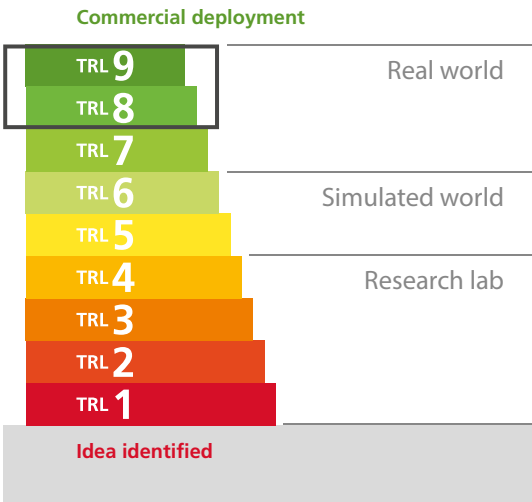
- [62] Schladör C., 2014. Schladör C., 2013. Theoretische und experimentelle Untersuchungen an einer trockenen Entschwefelungsanlage für Schiffsabgase. PhD thesis at University of Hamburg. In German. Pp. 199. tubdok.tuhh.de/handle/11420/1218.
- [63] Schladör C., 2014. Integration and operation of a dry scrubber system on a ConRo vessel. Ship & Offshore 2014, N 2.

LIME IN FGT AND WTE • Lime

in Flue Gas Treatment and Waste to Energy Incinerators

[sciencedirect.com/science/article/pii/S0956053X14005030](https://www.sciencedirect.com/science/article/pii/S0956053X14005030)
[sciencedirect.com/science/article/pii/S0956053X14005054](https://www.sciencedirect.com/science/article/pii/S0956053X14005054)

Type	Innovation action (product)
Partners	Leader/Lime: Unicalce (IT)  
Funding	Own initiative (IT) Funding rate: not reported
Duration	02.2010 – 12.2012
TRL	Technology Readiness Level: TRL 8-9



Contribution to 

Environmental protection – Improved technology – Raw material optimization – Energy efficiency.

REFERENCES:
[64] Binganzoli L., Racanella G., Rigamonti L., Marras R., Grosso M., 2015. High temperature abatement of acid gases from waste incineration. Part I: Experimental tests in full scale plants. Waste Management 36: 98-105.
[65] Binganzoli L., Racanella G., Marras R., Rigamonti L., 2015. High temperature abatement of acid gases from waste incineration. Part II: Comparative life cycle assessment study. Waste Management 35: 127-134.

Scope of work

In recent years, several waste-to-energy plants in Italy have experienced an increase of the concentration of acid gases (HCl, SO₂ and HF) in the raw gas. This is likely due to progressive decrease of the amount of treated municipal waste, which is partially replaced by commercial waste which is characterised by a higher variability of its chemical composition because of the different origins, with possible increase of the load of chlorine (Cl), fluorine (F) and sulphur (S). To address this challenge, intensive long-lasting tests were performed in four waste-to-energy installations in Italy using a specific dolomitic sorbent as a pre-cleaning stage, to be directly injected at high temperature in the combustion chamber.

Status of the project

Project finalized in 2012. The following results can be reported:

- By injecting around 6 kg of sorbent per tonne of waste, the decrease of acid gases concentration downstream the boiler was in the range of 7-37% (mean 23%) for HCl, 34-95% (mean 71%) for SO₂ and 39-80% (mean 63%) for HF [64].
- This pre-abatement of acid gases allowed to decrease the feeding rate of the traditional low temperature sorbent (sodium based) in all four tested plants by about 30%.
- Furthermore, it was observed by the plant operators that the sorbent helps to keep the boiler surfaces cleaner, with a possible reduction of the fouling phenomena and resulting in improved energy efficiency during the operation and reduce the climate change impact by 28% [64].
- LCA study underlines that is an eco-friendly and sustainable technology and in the comparison with the traditional operation 17 impact categories out of 19 are reduced [65].

CLEANER PORT (RENERE HAVN) ●

Lime fines as harbour cleaning technology

renerehavn.no/english

youtube.com/watch?v=DrFdLgRko08

Scope of work

Trondheim's port was badly affected by years of industrial activity, shipbuilding and the discharge of sewage, not to mention diffuse emissions, including air pollution, which contaminated the harbor with organic environmental toxins and heavy metals. The aim of the project was to ensure that environmental toxins in Trondheim harbor (Kanalen Brattørbassenget, Nyhavna and Ilsvika) would not exceed condition class 3.

Status of the project

Project finalized in 2016 Key achievements of this project report on:

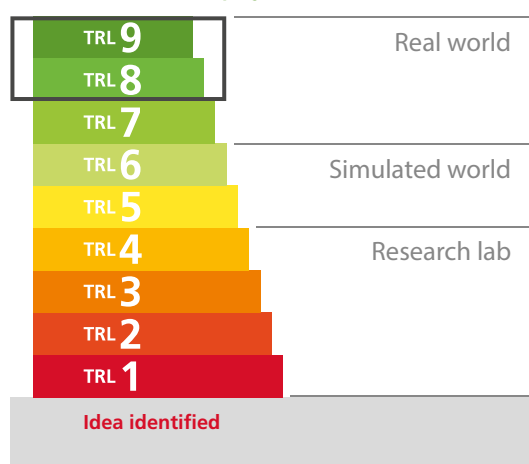
- The work in Trondheim consisted of dredging, dumping 75,000 m³ of seabed and capping around 400,000 m².
- Over two years the 'zero fractions' for the 'Cleaner Port' project in Trondheim, where the bottom of the harbour basin has been sealed with a layer of limestone in different gradings. Using mobile screening, the supplier supplied a substantial quantity from intermediate stores of fine fractions. In total, around 290,000 tons of limestone was supplied for this purpose.
- Limestone was delivered in 64 shiploads to reduce the carbon footprint and overall environmental impact. Capping was done by spreading clean, crushed limestone through a hatch in the bottom of a barge, with the process being repeated two or three times.
- GPS technology ensured that the stone ends up in the right place, while the thickness of the capping layer on the seabed was checked by means of surveying and visual inspection.
- When the stone is on the seabed, it forms a filter that prevents environmental toxins from leaching out. The capping materials were chosen on what would act as a filter for the sediment on the seabed and it itself be safe for the environment [66].

Contribution to

Avoid leachates – Seabed sealing – pH control – Digital technology.

Type	Innovation action (implemented)
Partners	Port of Trondheim; City council of Trondheim Lime: Franzefoss Minerals (NO) 
Funding	Total project: 221 Mill NOK
Duration	2014 – 2016
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



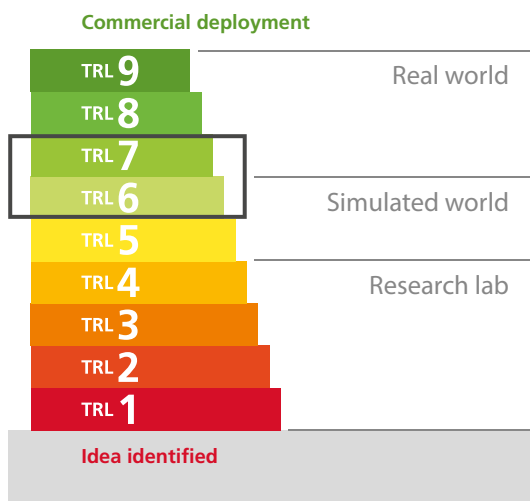
The harbor after capping.

REFERENCES:

[66] Franzefoss Minerals. 2016. Environmental Report 2016. Pp. 31, 51.

HARBOUR SLUDGE STABILISATION ●

Type	Innovation action (pilot)
Partners	Leader/Lime: Clogrennane (IE) 
Funding	Own company funding
Duration	02.2014 – ongoing
TRL	Technology Readiness Level: TRL 6-7



Lime stabilization practice applied on a barge.

Scope of work ●

A prominent harbour in southern Ireland required dredging for the safe passage of commercial and tourist fleets. The location is in one of Ireland's busiest tourist locations, known for its natural surroundings and picturesque amenities. Dredged material could not be moved directly inland due to its liquidity making it unsafe to transport. Because of the location, this material could not be treated on land prior to transport as it would have caused too great a visual impact.

Status of the project ●

The treatment of the harbour sediments demonstrated that:

- Working with a third party marine dredging specialist, Clogrennane implemented a programme of treatment which meant that dredged material could be stabilised while still on the extraction barges. This was done using a fine, medium reactivity quicklime which was injected into the sludge (see picture). The deep injection of quicklime served to stabilise the material prior to transport. Dust, noise and visual impacts were kept to a minimum. Low dust solution to the problem of drying/stabilising harbour sludge so that the material can be transported safely off-site. The concepts of this project were expanded to include larger, commercial ports, with several new locations treated using this method in 2017/2018.

Contribution to ●

Sustainable sludge treatment – Sediment valorisation – pH control – Low impact treatment of harbour sediments – Avoid visual impact – Avoid dust impact – Avoid noise impacts.

REFERENCES:

[67] clogrennane.ie/environment/sludge-treatment

P RUNOFF AVOIDANCE

Avoid Phosphorous runoff for healthier Baltic Sea

nordkalk.com/sustainability/community/baltic-sea-action-group

Scope of work

In agriculture, liming reduces the soil's acidity, which improves the plants' living conditions and allows them to use nutrients more efficiently, resulting in bigger crops and reduced nutrient runoff into watercourses. By liming of fields, the stabilization of sludge, and for lime filters and drains that help to reduce phosphorous runoff leakage and contribute to the recycling of phosphorus. This is extremely important because world's phosphorus reserves are estimated to last only for a few more decades. To address these challenges Nordkalk developed few projects for the soil and sea.

Status of the project

The following achievements can be reported from the multiple projects:

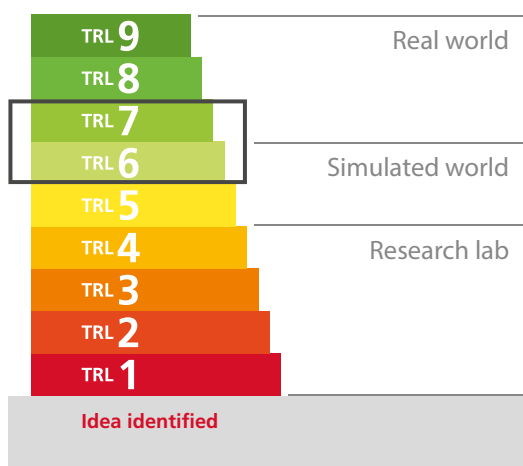
- In Finland, Structural liming has been tested in smaller scale in laboratories and on the fields. These tests help optimizing the correct spreading amounts for the Finnish soil types. Structure lime has been tested on the Finnish market since 2015.
- Another Nordkalk's many phosphorus-related research projects is also under way in Sweden. It involves structure liming and field testing in the fields surrounding lake Bornsjön near Stockholm. The project is being carried out in co-operation with Stockholm Water and the Swedish University of Agricultural Sciences.
- In 2012, Nordkalk joined the Baltic Sea Action Group (BSAG) in preserving the Baltic Sea with a 5-year-long commitment with the goal of reducing the phosphorus burden on the Baltic Sea.
- Nordkalk's commitment is ending, but work to reduce the phosphorus burden on the Baltic Sea and other water courses will continue.
- Increase the awareness of the environmental and crop benefits of liming in these areas is beneficial for the society [68].

Contribution to

P recovery – Sewage sludge stabilization – Phosphorus run-off avoidance.

Type	Innovation action (demonstration)
Partners	Stockholm water; BSAG; Swedish University of Agricultural Sciences Lime: Nordkalk (FI, SE) 
Funding	Total project: 2.5 Mill EUR
Duration	2012 – 2017
TRL	Technology Readiness Level: TRL 6-7

Commercial deployment



The Baltic Sea Action Group (BSAG) – officially "Foundation for a Living Baltic Sea" (Finland).

REFERENCES:

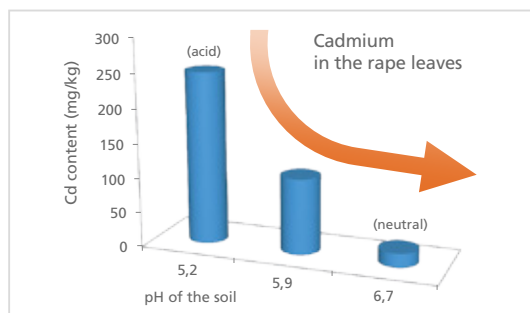
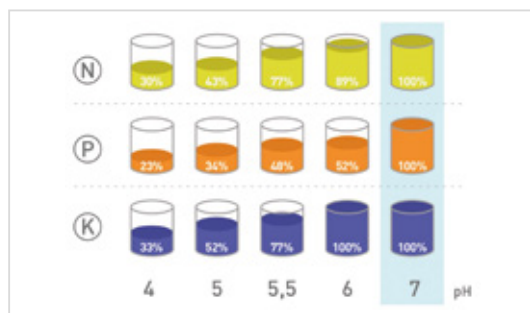
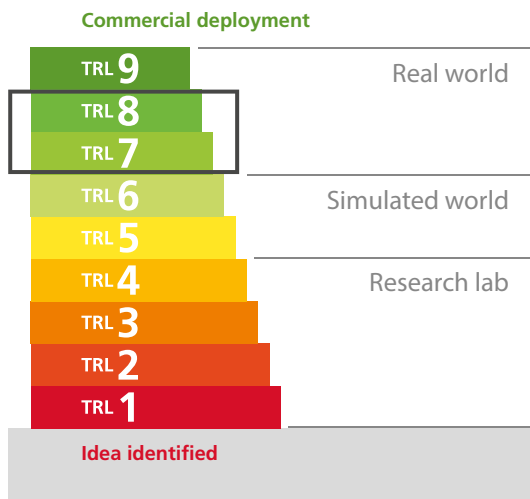
[68] Aurola A-M, Wellberg K. et al. 2018. Clay soil structure improvement & lime filters: Engineered solution to control phosphorus leakage. EU Sustainable Phosphorus Conference. 11-13 June 2018 in Helsinki (Finland). Poster presentation.

LIME IN AGRI 1 ●

Lime as a soil improver in Agriculture

carmeuse.com/improved-agricultural-soils

Type	Innovation action (demonstration)
Partners	Leader/ Lime: Carmeuse (FR) 
Funding	Own company initiative Total project: not reported
Duration	1995 – 2012
TRL	Technology Readiness Level: TRL 7-8



The soil improvement with pH increase.

Scope of work

The qualities of lime in agriculture application have been known extensively. Lime adjusts the soil pH from acid to basic to optimize the level of the crop growth, resulting in an increase of the production potential. This paper summarizes the benefits of using lime for farmers.

Status of the project

Project finalized in 2012 Key achievements of this project report on:

- It consolidates the soil structure and improves the air and water flows. This allows a better roots development and a better crop resistance to lack of water in draught periods.
- It optimizes the soil capacity, namely to retain fertilizers and make them available when needed by the crop.
- The effects of the fertilizers are enhanced. If the pH is close to neutral (pH 7), fertilizers are better absorbed by the plants. This avoids wasting fertilizers that can be harmful to the environment by leaching into underground water and rivers. A higher pH offers better conditions of aeration and humidity fostering the biological activity.
- With an acid soil (pH 4,5) only 30% of the Nitrogen (N), 23% of the Phosphorus (P) and 33% of the Potassium (K) spread on the field are absorbed.
- Plants growing on an acid soil absorb toxic elements (such as Aluminum, Cadmium) more easily. This limits the production potential and the crop quality [69, 70].

Contribution to

Agriculture – Crop growth improvements – pH control.

REFERENCES:

- [69] Ponchon F. 2016. La chaux aerienne et ses applications. Mines & Carrier. Pp. 47-56. In French.
- [70] Ponchon F. 2014. La chaux aerienne et ses applications. 64th Congress-Exhibition Societe de l'industrie Minérale (SIM 2015), 20-23 October 2015, Mons (Belgium).

LIME IN AGRI 2 ●

Natural solutions for sustainable agriculture

carmeuse-agriculture.com/your-applications/soil-amendment

Scope of work ●

The challenge for the future is to produce more food in an efficient and sustainable way. Agriculture needs then to follow what is called agroecology which is to focus on the interaction between elements of the ecosystem and productivity. Soil management is obviously a major part of this principles including efficiency, balance, diversity, co-creation of knowledge, recycling, synergies, human and social values, circular economies, cultural and food traditions, land and natural resource governance. Soil acidity is one of the limiting factor to allow to maximize yield and to preserve its reserves. A low pH will lead low fertility due to chemical toxicity, low fertilizer efficiency, compacted soil structure and limited biological life. Interest in correcting the soil pH and bring calcium is growing and it was needed to develop specific lime-based products allowing both an easy application and proven efficiency. Trials have been driven in the field during few years both in Romania and Hungary demonstrating the positive effect of this lime product application.

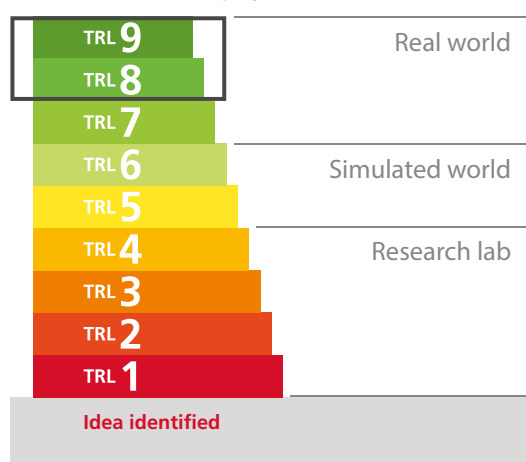
Status of the project ●

Project finalized in 2017:

- Aim of the project was to demonstrate the effect of new lime-based product to improve chemical, physical and microbiological properties of agricultural soils and to show both its effectiveness in a very short time and easiness to apply. Due to its granulated structure and high neutralizing value, the product could be applied directly with agricultural spreaders, using accurate doses (0.5 to 2 tons) per hectare. The first effects can be seen in just one to two months after the application. Moreover, in contact with water it dissolves and acts extremely rapidly [71, 72].
- Effect on soil structure was visible becoming lighter and more aerated thanks to increase of Calcium and flocculating effect.
- Optimum pH and structure allow good biological life and improved root development.
- Better nitrogen mineralization and nutrient availability like phosphorus and potassium has led to very significant yield improvement.

Type	Innovation action (demonstration)
Partners	Leader/ Lime: Carmeuse (RO, HU) 
Funding	Own company initiative Total project: not reported
Duration	2015 – 2017
TRL	Technology Readiness Level: TRL 8-9

Commercial deployment



Distinct growth rate on same acid soil upon liming.

- Product has a long term lasting action requiring one application every 3 to 5 years depending on soil type.

This innovative product won the 2016 Product Award for Hungarian Crops Growing [71].

Contribution to ●

Agriculture – Crop growth improvements – pH control.

REFERENCES:

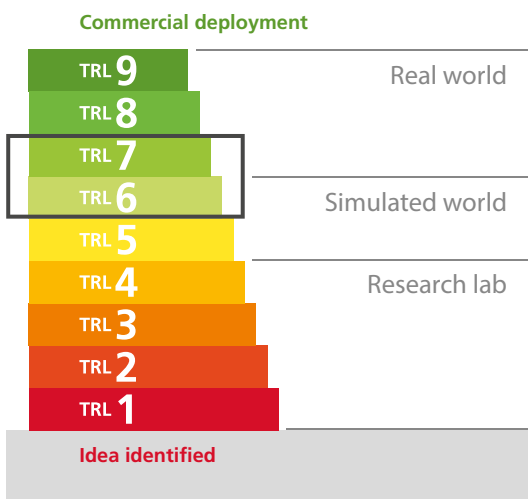
- [71] B. Costea. 2017. Calcium oxide, a solution for soil improvement. Lumea satului magazine. 02.10.2017. Bucharest (Romania).
[72] B. Costea. 2017. Romanian Agriculture Leadership Forum (RALF). 9.11.2017. Bucharest (Romania).

SOIL-WATER USE EFFICIENCY ●

Increasing water use efficiency in crop production through optimized liming – Development of an application model for agricultural implementation

fg-kalk-moertel.de/wasserhaushalt-boeden

Type	Innovation action (demonstration)
Partners	Leader: Kiel University (D) Lime: BV Kalk & DHG/Naturkalk 
Funding	National: 0.25 MILL EUR 
Duration	06.2016 – 11.2018
TRL	Technology Readiness Level: TRL 6-7



Extremely dried farmland gives not enough water for high yields.

Contribution to ●

Agriculture – Crop growth – pH control – Soil improvement – Soil structure – Agricultural lime.

Scope of work ●

Liming positively influences the soil structure by creating new connections between soil particles that are particularly stable and long-lasting. In addition, the biological activity in the soil is promoted, which in turn leads to the formation of continuous pore systems.

A well-developed soil structure improves the storage capacity for plant-available water and thus the site characteristics for crop production. Crop yield is stabilized, secured or improved, even against the background of the predicted climate change. The optimal lime supply is determined not only by the compensation of the annual land use-dependent soil acidification but also under the aspect of soil protection and optimal water absorption and storage, especially in clayey soils.

The project aims at developing an application model for the agricultural implementation of an optimized lime supply with respect to the soil structure, which helps to protect the soil from erosion and compaction, optimizes the storage capacity for plant-available soil water and thus secures or even increases yields in the long term.

To achieve the research objectives, extensive physicochemical and structural soil investigations are planned not only on disturbed, but also on undisturbed samples of different soils, which are characterized by different calcification intensities.

By developing recommendations that can be applied directly for liming on different soils, increased sales of lime fertilizers are expected.

Status of the project ●

- First field campaign results already show improvements concerning soil structure and porosity.
- Six month after application best results were achieved with utilization of 1.5x lime amount. in comparison to LUFA recommendations
- The higher the amounts of clay in the soil the higher the liming effect is expected.

LIME IN GLASS MAKING ●

Use of lime in Glass making

carmeuse.eu/news/carmeuse-value-fiberglass-icg-istanbul

Scope of work

Glass making is an energy intensive process. As part of providing technology and environmental improvements down the value chain to multiple applications, lime producers have made an assessment for the use of pre-calcined lime in glass making and ensure the same functionality of the glass end-product. The tests performed so far at lab scale have indicated some encouraging results on quality and have allowed to evaluate the positive impact on energy and CO₂ balance.

Status of the project

Lab study demonstrates that:

- Quality of glass is not negatively impacted by the conversion to oxides. After 2 hours of melting, similar glass quality; No significant impact on viscosity is observed.
- Lime use leads to better stability of properties.
- Use of burnt products has a positive impact on energy consumption and global CO₂ emissions: CO₂ savings up to 350 kg/ton of glass thanks to 99% savings on calcination and reduced CO₂ on melting thanks to 40% energy savings; transport CO₂ savings; concentration of CO₂ in 1 place (lime production plant) [73].

Contribution to

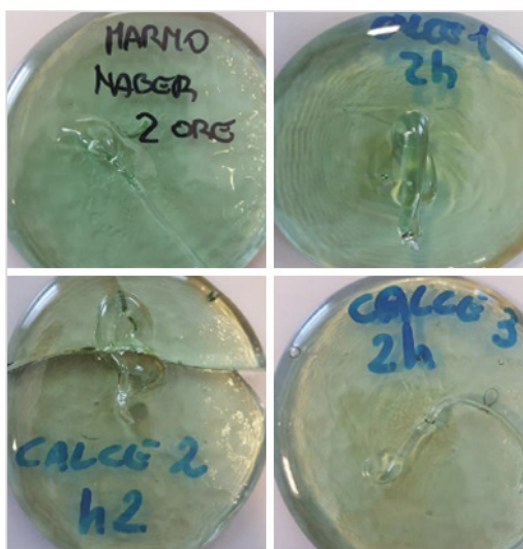
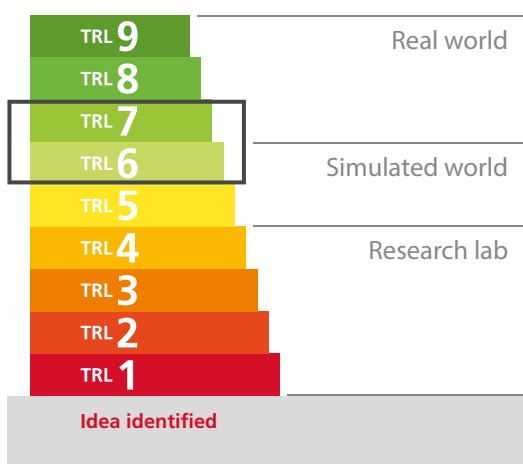
Glass application – Energy efficiency – Lower carbon footprint.

REFERENCES:

[73] Somerhausen B., Di Marino E., Hunturk T., Tiozzo S., Ceola S. 2017. Benefits for fiber glass producers to use calcium oxide in their raw material. Platform presentation at ICG Annual Meeting in November 2017 in Istanbul (Turkey).

Type	Innovation action (demonstration)
Partners	Leader: Stazione Sperimentale del Vetro (IT) Lime: Carmeuse (TR)
Funding	Own funding
Duration	04.2017 – 11.2017
TRL	Technology Readiness Level: TRL 6-7

Commercial deployment



The Glass making with lime.

6. Innovation in Sustainability Tools

- STYLE
- LCI of Lime
- Lime audits



STYLE

Sustainability Toolkit for easyY Life-cycle Evaluation

spire2030.eu/style

Scope of work

The Sustainable Processing for Resource and Energy efficiency (SPIRE) Roadmap calls for an industry-focused study of current sustainability assessment approaches across the process industries, with the aim of identifying and promoting a suitable 'toolkit'.

Project STYLE has three key objectives:

- Identify best practice in sustainability evaluation, across sectors and through value chains via inventory and classification of established approaches.
- Test and deliver a practical toolkit for sustainability evaluation of processes and products, spanning multiple sectors and easily usable by non-practitioners of LCA.
- Determine gaps, through critical assessment and validation, and identify future research needs to improve the toolkit and ensure broad applicability across sectors.

Status of the project

Project finalized in December 2016. Key deliverables of STYLE consist of:

- Inventory of known tools, methodologies and approaches for sustainability evaluation.
- Characterisation and assessment of a tools suitability & selection of tool(s) to be tested on industrial processes across multiple sectors.
- Critiques of the tools' effectiveness, applicability and barriers to use via Toolkit framework.
- Critical analysis and identification of future research needs and steps required to increase uptake of tools across industry sectors and value chains via the STYLE Roadmap [74, 75].

Contribution to

Sustainability tools – Cross sectoral – Sustainability assessment.

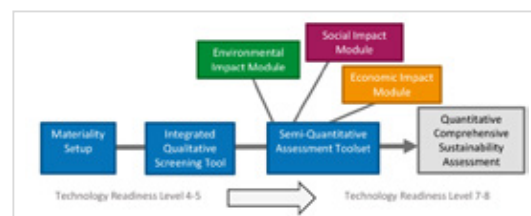
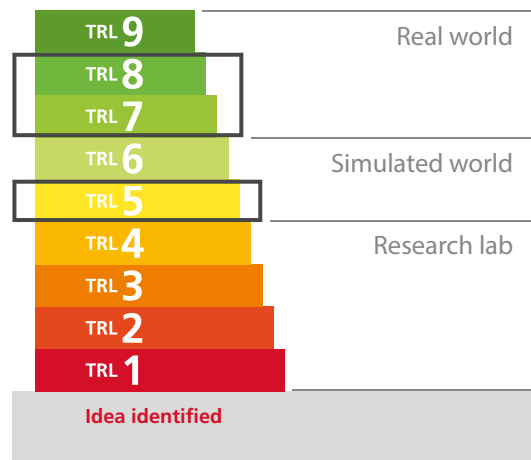
REFERENCES:

[74] SPIRE. 2016. STYLE Toolkit Framework. 2016. spire2030.eu/sites/default/files/users/user221/STYLE/STYLE-IdealToolkitFramework.pdf.

[75] SPIRE. 2016. STYLE Roadmap. 2016. spire2030.eu/sites/default/files/users/user221/STYLE/STYLE-Roadmap.pdf.

Type	Coordination support action (sustainability)
Partners	Leader: Brittest (UK) Lime: Carmeuse 
Funding	EU / H2020 / SPIRE Total project: 0.5 Mill EUR EU contribution: 0.5 Mill EUR 
Duration	01.2015 – 12.2016
CSA	Coordination Support Action (Sustainability): TRL 5 to 7-8 (expert judgment)

Commercial deployment



Ideal Toolkit Framework [74].



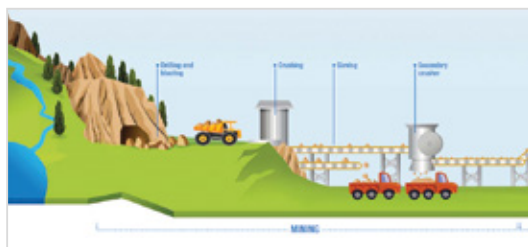
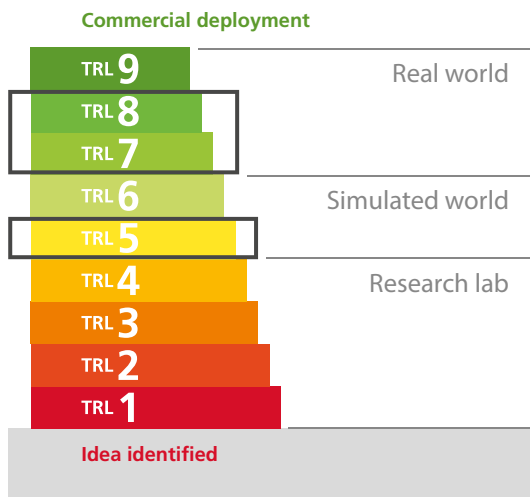
Recommendations Roadmap [75].

LCI OF LIME ●

Assessment of lime extraction and production in Europe through a Life Cycle Inventory approach

eula.eu/topics/environmental-impact-assessment-lca-life-cycle-assessment; eplca.jrc.ec.europa.eu/ELCD3/processSearch.xhtml

Type	Coordination support action (sustainability)
Partners	Leader/Lime: EuLA (EU) 
Funding	Own industry initiative
Duration	2011 – 2017
CSA	Coordination Support Action (CSA): TRL 5 to 7-8 (expert judgment)



The three main process steps consisting of mining, calcination and hydration.

REFERENCES:

- [76] Shtiza A., Danvers J., E. Despotou E., 2014. The value of LCI data in sustainability and market development: case of the lime data. 8th International Conference of Society & Materials (SAM 8), Liège, (Belgium). 20-21 May 2014. Poster presentation.
- [77] Shtiza A., Verhelst F., 2014. The value of EuLA life cycle inventory (LCI) data to conduct LCA studies & their applicability. Science-Industry Roundtable: The use of lime in mortars. Guimarães (Portugal). 10 July 2014. Platform presentation.

Scope of work ●

European Lime Association (EuLA) covers 95% of the European lime production in Europe. Lime is a versatile material which is used in many different applications, such as in steel, agriculture, environment, chemical industry and so on. Due to increasing demand about the environmental impacts of products placed on the market, EuLA has used a scientific and quantitative approach (i.e. Life Cycle standard series ISO 14040-14044) to answer the requests for the environmental footprint of lime products at the use phase but also to define management strategy at quarry/processing facility.

Status of the project ●

Project was finalized in 2011 and the following can be reported:

- Life cycle inventory (LCI) from cradle (limestone extraction) to gate (lime plant) in is based on data for the reference year 2007, which were provided from the different lime manufacturers across Europe.
- The outcome of the EuLA LCI study is the most comprehensive and representative set of European data provided from the lime manufacturers for the production of quicklime and hydrated lime, which covers up to 73% of the total European lime production.
- In accordance with the ISO requirements, the outcome of the study was validated by an external critical reviewer.
- This inventory provides valuable and reliable data also to downstream users intending to carry out their own LCA to cover their products. In the period 2011-2016 around 63 requests were responded at EuLA level.
- To assess the most recent environmental footprint of lime products., a revision of the EuLA LCI is ongoing during 2017 [76, 77].

Contribution to ●

Life Cycle Assessment – Value chain sustainable management – Innovation – Improve performance – Communication.

LIME AUDITS ●

eula.eu

Scope of work ●

The access of raw materials and their sustainable management are a challenge that lime extraction and manufacturing companies have incorporated in their management practices through the practice of auditing of the operations on-site and off-site in cooperation with multiple value chain stakeholders. The audits assist in the monitoring of the handling of the extraction, processing, transport and storage of lime products.

The key objectives of these audits are:

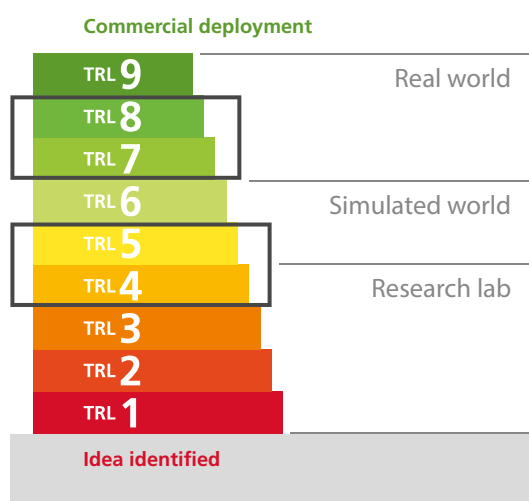
- Optimize the raw material recovery at the quarry site.
- Minimize the amount of waste.
- Determine gaps and corrective actions to ensure that handling, transport and storage conditions assist in meeting these objectives.

Status of the project ●

The audits are an ongoing practice and key deliverables consist in:

- Established of multi competence expert teams within their Application & Development teams.
- Perform performance audits on-site, by internal and external inspectors (energy efficiency, health & safety; handling, environmental, ...).
- Perform "Lime Audit" at customers sites. The goal is to locate potential shortcomings in Lime handling and day to day operational use by the local operators.
- The scope of the Surveys include transportation to the site, storage facilities, conveying, charging, discharging and weighing equipment.
- These audits, have shown that better handling (i.e. Lime exposure to humidity and Lime ending up as hydrate in the dedusting facilities, or, the generation of fines in lump Lime handling) can result in improved resource optimization and cost reduction for the user.
- The audit result help to monitor developments an assess whether corrective measures are delivering and improve handling and the product performance on-site and off-site [78].

Type	Innovation action
Partners	Leader/Lime: EuLA (EU) 
Funding	Company initiatives Total project: not reported EU contribution: not applicable
Duration	1980 – ongoing
TRL	Technology Readiness Level: TRL 4-5 to 7-8 (expert judgment)



Contribution to ●

Resource optimization – Waste minimization
– Value chain management – Sustainability integrated actions.

REFERENCES:

[78] 2014. Xella: Sustainability report 2014. Ecoloop project.

7. Innovation in Carbonation

- Mortars
- Soil Stabilization



MORTARS •

Carbonation in lime mortars

eula.eu

Scope of work

The main objectives of this project were:

- Assess the literature on the carbonation of lime in mortar applications based on relevance, reliability and adequacy.
- Comparative assessment to highlight the differences in the environmental impact between various mortars/renders/lasters, and assess sensitivity of some parameters (e.g. lime content) on the results.

Status of the project

Project finalized in 2012. The following findings can be reported:

- A carbonation front moves progressively from mortar surface exposed to the atmosphere to depth of the mortar. Carbonation levels in ancient and new air lime mortars varies generally in the range of 80% to 92% of the amount of hydrated lime used in the formulations [79].
- The carbonation front progresses around 190 mm for 100 years. Fastest carbonation rate is within the first years (i.e. 20 mm end of first 400d).
- The LCA results show that, the impact of the carbonation is the highest for the mortars or renders with the highest lime content. CO₂ footprint is reduced by 3% (cement based mortars) to 17% (lime based mortars).
- Considering carbonation, will change the overall carbon footprint for the lifetime of mortars/plasters [80].

Contribution to

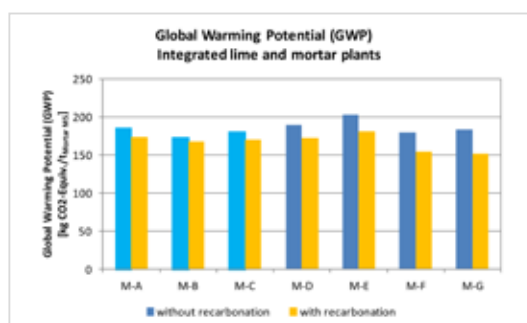
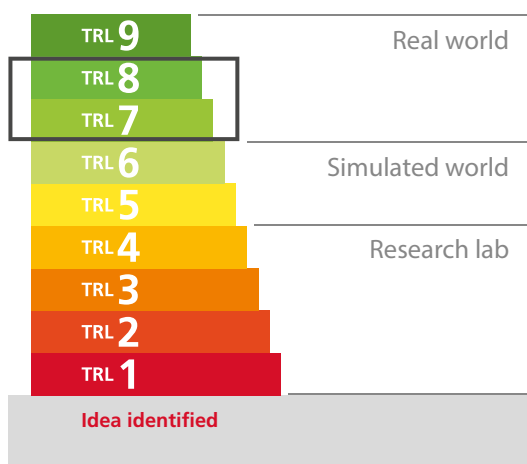
Lime carbonation – Lower carbon footprint – Intelligent building skins.

REFERENCES:

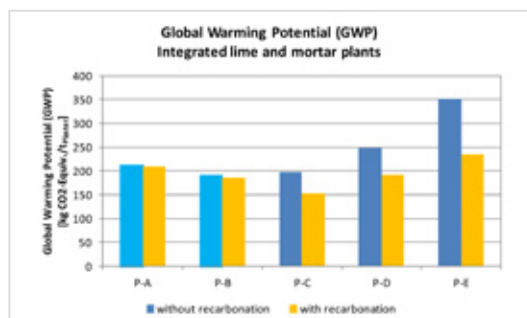
- [79] Schlegel T., Shtiza A., 2015. Environmental footprint study of mortars, renders and plasters formulations with no, low or high hydrated lime content. Mauerwerk 19: 5. Pp. 370-382. In English & German.
- [80] Despotou E., Schlegel T., Shtiza A., Verhelst F., 2016. Literature study on the rate and mechanism of carbonation of lime in mortars. Mauerwerk 20: 2. Pp. 124-137. In English & German.

Type	Innovation action (sustainability)
Partners	Leader/Lime: EuLA (EU) 
Funding	Own initiative Total project: not reported
Duration	09.2011 – 09.2012
TRL	Technology Readiness Level: TRL 7-8

Commercial deployment



Results from the comparative LCA for mortars [79].



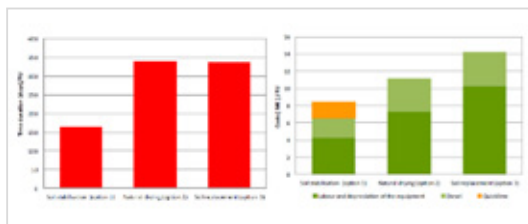
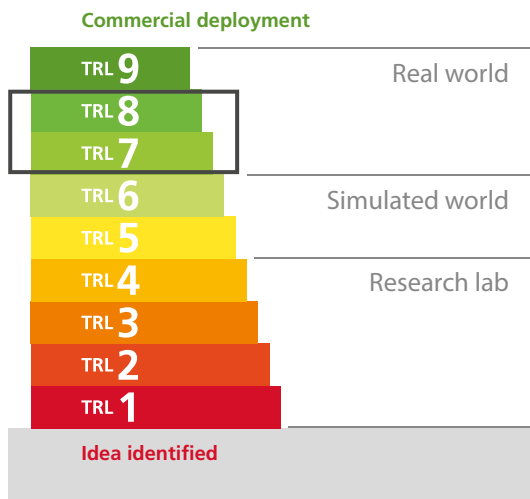
Results from the comparative LCA for plaster [79, 80].

SOIL STABILIZATION ●

Carbonation in soil stabilization

eula.eu

Type	Innovation action (sustainability)
Partners	Leader/Lime: EuLA (EU) 
Funding	Own initiative Total project: not reported
Duration	09.2012 – 04.2014
TRL	Technology Readiness Level: TRL 7-8



Timeline to complete the works and cost savings.

REFERENCES:

- [81] Haas S., Ritter H.-J. 2018. Soil improvement with quicklime – long-time behavior and carbonation. Journal Road Materials & Pavement Design by Francis & Taylor. Accepted. doi.org/10.1080/14680629.2018.1474793.
- [82] Shtiza. 2016. La carbonatation de la chaux: Analyse du cycle de vie et analyse des coûts du cycle de vie dans les applications au traitement des sols & mortiers. Mines & Carrières. Pp. 69-74. In English with French abstract.
- [83] Denayer C., Verhelst F., Danvers J., Despotou E., Shtiza A., 2014. Linking environmental studies with natural carbonation: Case of two lime applications. 20th LCA Symposium Novi Sad (Serbia). 24 November 2014. Platform presentation.

Scope of work

The use of lime in soil treatment is widely known to improve the quality of soils for Civil engineering application. The effect is lime is widely documented for its benefits, and the carbonation reaction although known, has not been quantified. The main objectives of this project were:

- Perform tests to a German road build 34 years ago to measure qualitatively and quantitatively the carbonation of lime in soil stabilization at a depth of 10 m. The selection of the site was relevant because similar study was performed 11 years after construction.
- The findings from the German study, were applied to a real soil stabilization project in France.

Status of the project

Project finalized in 2014. The following findings can be reported:

- The case study in a road in Germany, where the soil stabilization with lime was carried out 25 years ago indicated that carbonation rate is ranging between 35-40%. 10-15%: still available as free CaO and 50% is used for pozzolanic reactions. These results were obtained from the application of various techniques, such as X Ray Diffraction, Phenolphthalein as well as geochemistry modelling [81].
- When comparing: 1. Soil stabilisation with quicklime for the re-use of wet soils. 2. Natural drying of wet soils before re-use and 3. Replacement of wet soils by external suitable soils, the time to complete the works is shorter for option 1 and the cost savings by using lime soil treatment for the soil stabilization are in the range of 22% and 42% if compared to the natural drying (option 2) or Soil replacement (option 3) [82, 83].

Contribution to

Lime carbonation – Lower carbon footprint – Soil stabilization.

8. Innovation at End of Life

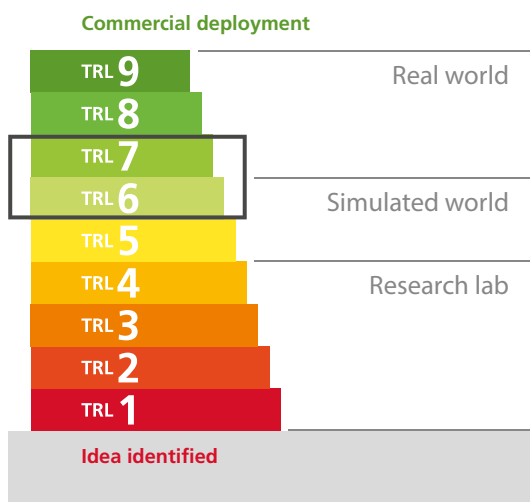
- LODOCAL
- P recovery
- P recovery from Digestate
- PLASMETREC
- PLD
- Re-BioP-Cycle



LODOCAL • Lime to sanitize sludge from waste water for use in agriculture

cordis.europa.eu/news/rcn/128630_en.html

Type	Innovation action (product)
Partners	Leader/Lime: Calcinor (ES)   
Funding	National INTEK-BERRI (ES)
Duration	02.2009 – 12.2011
TRL	Technology Readiness Level: TRL 6-7



Contribution to Environmental protection – Materials technology – End of life treatment.

REFERENCES:

- [84] La cal como tratamiento avanzado para lodos de EDAR. INFOENVIRO Issue 56. July 2010. In Spanish.
- [85] Utilización de la cal en tratamiento de aguas lodos. Aspectos técnico-comerciales y estrategia de desarrollo del Mercado. CONCAL 2012 event. Platform presentation. In Spanish. an-fa-cal.org/media/Eventos/PRESENTACIONES_DEL_EVENTO_CONACAL_2012/Utilizacion_de_la_cal_en_tratamiento_de_aguas.pdf.
- [86] Usos de la cal en tratamiento de agua potable. 2012. ANFACAL. Pp. 7. In Spanish.

Scope of work

The sludge originated by wastewater treatment plants are governed by very tight requirements through legislations/EU directives. However, they can be purified and later reused in the field as mulch or for composting. Faced with stronger requirements, the industry looks for viable alternatives to current uses, which enable them to sell this by-product.

Several studies have shown that adding lime to the sludge can eliminate pathogens. Specifically, lime can help to create physicochemical conditions which can stop the biological degradation of organic matter they contain, avoiding thus the production of odors.

The scope of the project was to demonstrate that the application of lime enables sludge sanitation, either for reuse for soil improvement as a sanitized agricultural amendment, or for regeneration of degraded environments without risk to plant, animal or human health.

Status of the project

Project finalized in 2011. The following results can be reported:

- The WWTP sludge treatment with lime, sanitizes, reduces the concentration of bacteria below the detection limits.
- Stabilizes the sludge in the long term by avoiding the decomposition of organic matter and reduces its moisture, thereby facilitating handling.
- Thus, the results obtained to date suggest that this study will provide a solution to sanitize the wastewater treatment plant sludge and that they may continue to apply with full guarantees of safety in agriculture.
- Propose a scheme of the facility needed to move the application to an industrial level, the size of which depend on both the type of sludge treatment plant and the volume to be processed [84, 85, 86].
- Sludge legislation must be agreed inside and between the countries.

P RECOVERY ●

Development of a crystallization process for re-covering P fertilizers from ww purification with complete recovery of the remaining phases in the cement industry

fg-kalk-moertel.de/forschungsberichte

Scope of work

In Germany, the current use of phosphate fertilizer is around 110,000 t/year. Average phosphate content in sludge is 4% to 6% (approx. 25,000 t phosphate p.a.) in Germany. Phosphate recovery from sewage water for utilization as fertilizer and usage of residual phases within the cement industry was tested. Through process optimization, the recovery of phosphate-containing phases with lime products, the use of metal salts can be minimized to maintain the run-off parameters.

Status of the project

Project finalized in 2016. The following achievements can be reported:

- Development of a crystallization process for recovering phosphate fertilizers from the waste water purification process with complete recovery of the remaining phases for use in the cement industry.
- Trials at the Giessen sewage treatment plant completed: Successful P recovery and fertilizer production
- Plant tests at the University of Bonn, have demonstrated and validated the effectiveness and plant availability of P within the crystallization product [87].

Contribution to

P recovery – Sewage sludge treatment & management – Fertilizer industry – Agriculture – Co-incineration processes.

REFERENCES:

[87] Ehbrecht A., Ritter H.-J., Schmidt S.-O., Schönauer S., Schuhmann R., Weber N. 2016. Entwicklung eines kombinierten Kristallisationsverfahrens zur Gewinnung von Phosphatdünger aus dem Abwasserreinigungsprozess mit vollständiger Verwertung der Restphasen in der Zementindustrie. Final report. Pp. 75.

Type Innovation action (pilot)

Partners Leader/Lime: BV Kalk (DE)



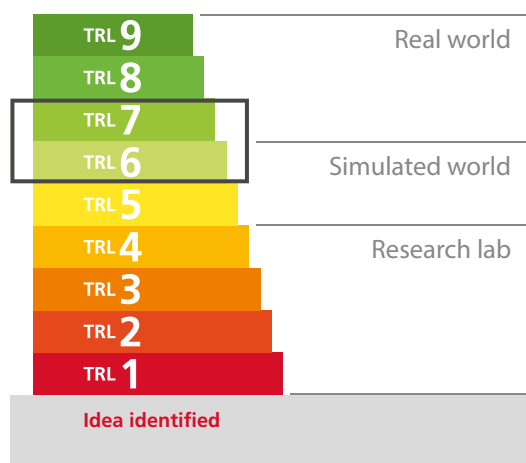
Funding National: 0.45 Mill EUR



Duration 11.2013 – 04.2016

TRL Technology Readiness Level:
TRL 6-7

Commercial deployment



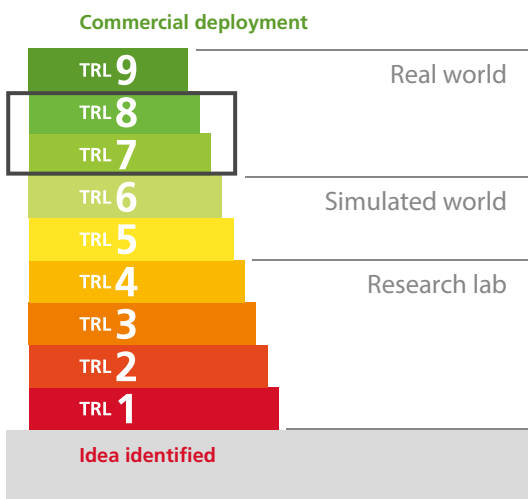
Pilot plant for the recovery of Phosphate from sewage sludge and planting tests performed by University of Bonn (DE).

P RECOVERY FROM DIGESTATE ●

Phosphorous recovery from Digestate

byosis.com/wp-content/uploads/2017/03/
Artikel-Boerderij-2017-Feb.pdf

Type	Innovation action (demonstration)
Partners	Leader/Lime: Lhoist (NL) 
Funding	Own initiative Total project: not reported
Duration	2012 – 2017
TRL	Technology Readiness Level: TRL 7-8



Usable fertilizers stripped from digestate.

Scope of work ●

The abolition of the milk quota on 1st April 2015 led to a growing dairy cattle stock in the Netherlands. The consequence is that the animal manure puts an increasing pressure on the environment.

Phosphate and nitrogen are needed as fertilizer, but when these minerals are not absorbed by the crops they leach in the soil and pollute the ground water. For this reason, farmers are strictly regulated in the period and amount of phosphate and nitrogen they may use on their land. Also, the need for e.g. nitrogen and phosphorous varies in the growth season depending on the crop availability and the soil type. Many farms struggle to stay within these limits and have to balance the demand for nitrogen and phosphorous with the supply. The project has been carried out at a farm with approximately 500 dairy cattle. The animal manure is digested together with co-products in an anaerobic digestion plant. At the end of this process around 25000 ton digestate is produced each year, high in nitrogen and phosphate.

Status of the project ●

Together with technology partner Lhoist has developed a process to recover and concentrate nitrogen and phosphate from digestate in separate fractions by a physico-chemical treatment with a specially developed lime-based product.

By this, 18.00 tons of a thin fraction can be produced, which contains less than 20% of the initial nitrogen and phosphor. The nutrients are concentrated in a stream of ammonium sulfate and a phosphate fertilizer and can be valorized where needed [88].

Contribution to ●

P recovery – P & N runoff avoidance – Transport reduction – Fertilizer valorization.

REFERENCES:

[88] Poelsma, Bouke. Bruikbare meststoffen gestript uit digestaat. Boerderij 102, no. 22. Pp. 20-21. In Dutch.

PLASMETREC ●

Reverse Metallurgy: Plasma Metal Recovery

reversemetallurgy.be/fr/axes.html?ID=83

Scope of work

The circular economy objective is to valorize the industrial waste through the recycling and ensure that secondary raw materials (especially non-ferrous metals and critical raw materials) become part of the value chain. Reverse Metallurgy Public Private Partnership (PPP) responds to these strategic objectives of Wallonia region in Belgium, which objective is to become a center of excellence for the recycling and recovery of non-ferrous and critical raw materials.

The objective of Reverse metallurgy lies in the technology development for plasma oven to process a multitude of secondary raw materials and valorize non-ferrous materials, some of them being critical, for the European industry. Hydrometallurgical treatments are carried out upstream of the oven to improve the quality of end products.

Status of the project

Project ongoing until 2021. The following objectives can be reported:

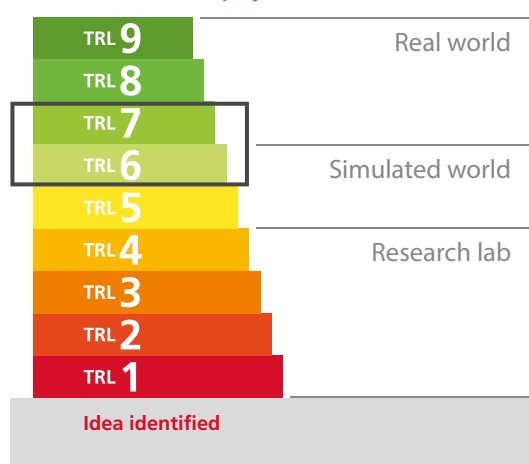
- Commission a pilot facility consisting of oven, gas treatment and metal feed and concentration units on the Hydrometal site in Engis.
- Investigate multiple non-ferrous waste flows at CRM and assess technical and economic feasibility at the pilot facility.
- Carmeuse will contribute with the expertise on flue gas treatment to minimize the polluted emissions.
- University of Liege will contribute with the expertise on mineral characterization.
- The ultimate objective will be to adapt and optimize the functioning of the pilot facility that's to the tests and identify the raw materials to feed the industrial facility in the future [89, 90, 91].

Contribution to

Recycling – Circular economy – Non-ferrous metal recovery – Materials technology – Raw material optimization – Critical raw materials.

Type	Innovation action (demonstration)
Partners	Leader: Hydrometal (BE) Lime: Carmeuse
Funding	National PPP (BE, Wallonia) NEXT programme + industry partners (9 Mill EUR)
Duration	01.2016 – 12.2021
TRL	Technology Readiness Level: TRL 6-7

Commercial deployment

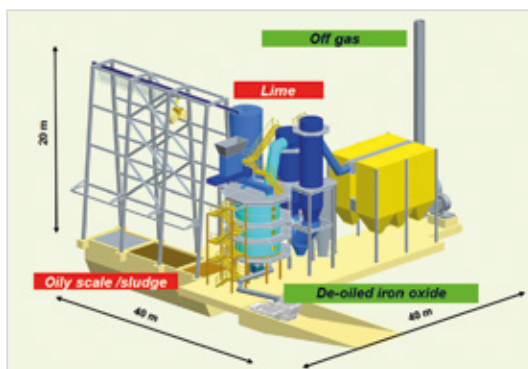
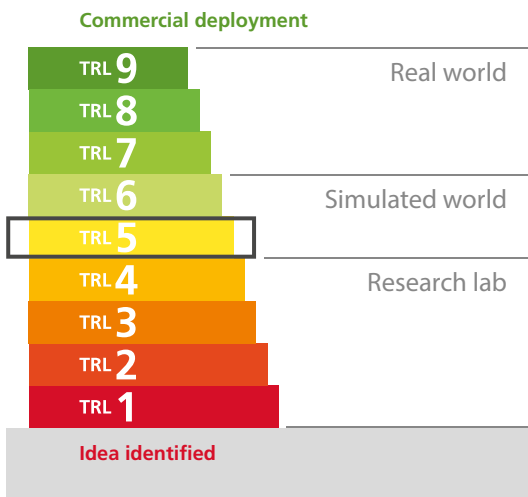


Timeline to complete the works and cost savings.

REFERENCES:

- [89] Bechet M., La siderurgie Wallonne n'es pas morte. La Dernière Heure. Pp. 16-17. In French.
- [90] ULg lance les robot trieurs de déchets. La Meuse. Pp. 8-9. In French.
- [91] 2016. Recycling Valley: Innovative Reverse Metallurgy in Wallonia and in Europe. Conference 21 November 2016. Liege (Belgium).

Type	Innovation action (process)
Partners	Leader: Paul Wurth (LU) Lime: Lhoist
	  
Funding	EU / LIFE+ Total project: 13 Mill EUR EU contribution: 4.9 Mill EUR
	
Duration	09.2012 – 09.2015
TRL	Technology Readiness Level: TRL 5



Simplified process flow sheet of the PLD process [92, 93].

REFERENCES:

- [92] Rodriguez D., Pelletier M., Houbart M., 2013. De-oiling of oily mill sludge and scales. Associação Brasileira de Metalurgia, Materials e Mineração (ABM) – 50th Rolling seminar in Ouro Preto (Brazil) on 19 November 2013. Pp. 1-9.
- [93] Pelletier M., Rodriguez D., Houbart M., 2014. De-oiling of oily mill sludge and scales. European Steel Technology & Application Days (ESTAD) at Paris (France) on April 2014. Pp. 2.

Scope of work

The main objectives of the PLD project are:

- De-oiling of oily material by means of an innovative low-temperature and auto-thermal process using lime and testing at full industrial scale.
- Recycle of PLD end-product in sinter plant as substitute of raw material (iron ore) and reduce steelmaking waste amount.
- Improving energy consumption in comparison with existing processes.
- Reduce soil and water pollution related to waste landfilling.
- Application to worldwide iron and steelmaking industry.
- 100% of PLD end-product into sinter plant as substitute of iron ore.
- Adapt PLD process to other oily waste.

Status of the project

Project finalized in 2015. The following achievements can be reported:

- By means of the pilot test, efficiency of PLD process efficiency was proven at Paul Wurth lab and efficient de-oiling rate was achieved to recover pure iron ore fines.
- Market analysis, focusing on securing sufficient oily sludge supply from different industrial sites to operate the PLD pilot plant.
- Identification of the site to construct the PLD plant has been selected and local authorities have been approached to start construction permit application.
- Due to the long delay compared to the initial LIFE project time schedule, the low amount of oily by-products available and the refusal of the local authorities to issue a construction permit due to urban reasons, the partners were forced to end the project in May 2015 [92, 93].

Contribution to

Lime technology – Steel making – Circular economy – Waste valorization.

RE-BIOP-CYCLE ● Recycling Phosphate from communal sewage treatment plants by Bio-P re-dissolution and crystallisation in a fluidised bed reactor

fg-kalk-moertel.de/re-biop-cycle

Scope of work

In agriculture, the application of mineral fertilizer becomes necessary as the soil loses its nutrients over time. Among the most important is Phosphor (P), which is mainly recovered from P mines. One common problem using these resources is the increasing contamination with radiogenic Uranium and Cadmium, both of which end up in fertilizer in concentrations that violate national and international regulations.

Therefore, secondary, uncontaminated P-resources like sewage sludge are gaining more and more attention. The Re-BioP-Cycle project aims at recovery of P from activated and excess sludge by optimising the Bio-P process at a sewage treatment plant in Gießen, Germany. The phosphates are recovered without any endocrine active substances or organic contaminants. In a fluidized bed reactor, the extracted phosphates will react with (dolo-) limestone to calcium phosphate and struvite, which can be readily used as fertilizers in agriculture.

With a P recovery rate of > 50%, the Re-BioP-Cycle project will adhere to the new sewage sludge regulations in D from 2025 onwards while providing a sustainable, cross-industry solution for economic recycling and reuse of secondary P. The end-product will allow a controlled agricultural use of P, thus helping to reduce costs and to avoid overfertilization.

Status of the project

Project started in January 2018:

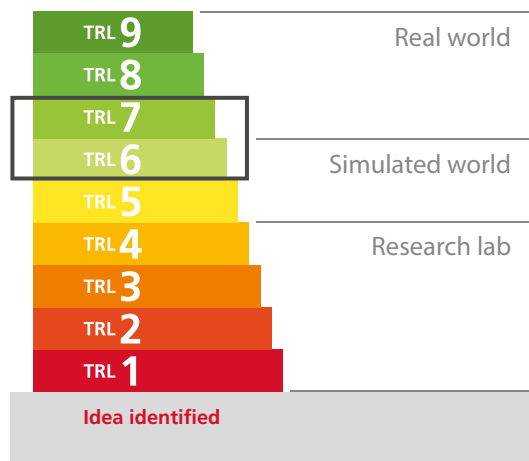
- At the moment, laboratory scale pilot tests are taking place which focus on optimising the fluidized bed reactor and the Bio-P process.
- First pilot scale experiments will be carried out in the end of 2019.

Contribution to

Environmental protection – Materials technology – End of life treatment.

Type	Innovation action (plant)
Partners	Leader/ Lime: BV Kalk (DE) Partner: THM  
Funding	National: 0.5 Mill EUR  
Duration	01.2018 – 06.2020
TRL	Technology Readiness Level: TRL 6-7

Commercial deployment



Aerial view of the Sewage Treatment Plant in Gießen (DE).

9. Future Technological Innovation Priorities for the lime sector



The lime industry sector although small is an important sector due to its enabling nature and embedded in different value chains. Being an energy intensive sector, (70% of its CO₂ emissions are due to the decarbonation of the raw material), the lime industry's first priority is to find ways to mitigate those [94]. As you can see from this brochure extensive work has been done by the sector to address this challenge through multiple innovation actions/projects.

However, still a lot remains to be done. Finance to cover high risk investment from TRL 6 to TRL 9, is necessary to industrialize pilot findings. Technically and economically feasible CCU development could provide a sustainable solution for these emissions.

In a recent assessment, the lime industry agreed to focus on projects providing solution on **getting the CO₂ in some form of fuel and make it part of the fuel chain**, as for instance:

- Bioethanol.
- Biomass.
- Oxyfuel.

Few ideas for future innovation projects could be:

- Increase CO₂ concentration e.g. by looping.
- Indirect calcination.
- Methanisation.
- Low concentration CO₂ => Direct use for e.g. plant/algae/bacteria growth/feeding or flue gas cleaning.
- Combination with Oxyfuel process.
- Carbonation of mortars.
- Carbon dioxide Storage by Mineralisation (CSM).
- Storage of renewable energy by combination of Lime "Oxyfuel Process" with CO₂ – looping and methanization.
- Marine diesel desulphurization.

European Lime Industry is committed to provide sustainably produced products always caring about nature preservation, climate change mitigation technologies, energy efficient processes. Continuous improvements in technology innovation, health and safety at work place thus accompanying the current pathway towards an economically robust circular economy.

REFERENCES:

[94] EuLA. 2014. A Competitive and Efficient Lime Industry, Cornerstone for a Sustainable Europe (Lime Roadmap). Pp. 72.

10. Annexes



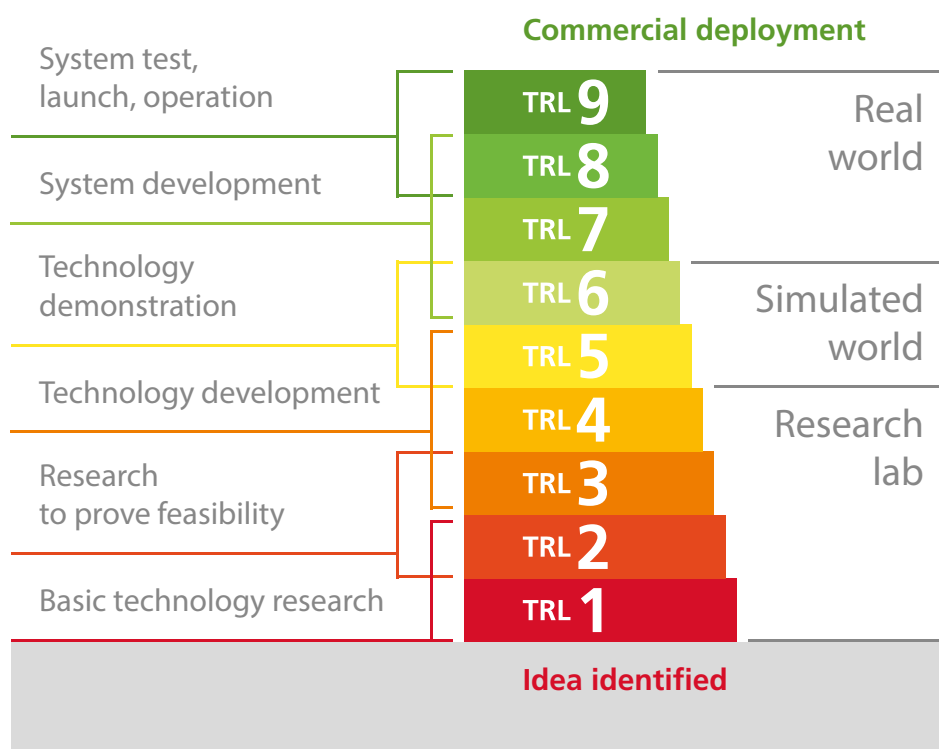
Annex 1: Technology Readiness Levels (TRL scale)

Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified [95]:

- TRL 1 – basic principles observed.
- TRL 2 – technology concept formulated.
- TRL 3 – experimental proof of concept.
- TRL 4 – technology validated in lab.
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 7 – system prototype demonstration in operational environment.
- TRL 8 – system complete and qualified.
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies, or in space).

REFERENCES:

[95] ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf.



Annex 2: EuLA Innovation Task Force

This work was performed under the supervision of the European Lime Association (EuLA) Innovation Task Force. The support of experts contributing to the task force deliverables is greatly acknowledged.

To refer to this report please use the following reference: © EuLA. 2018. Innovation in the lime sector 2.0. Pp. 1-84.

THE COMPOSITION OF THE EuLA INNOVATION TF AT THE TIME OF WRITING THIS REPORT WAS:

Chairman:

Danvers Julian (Carmeuse)

Secretary:

Despotou Eleni (EuLA)

Shtiza Aurela (IMA-Europe/EuLA)

Active Members EuLA Innovation TF:

Aladro Vico Jorge (Ancade)

Boekendorf Ulf (Fels)

Connolly Joe (Clogrennane Lime)

Costea Bogdan (Carmeuse)

Creveceour Stephane (Carmeuse)

Foster Steve (SingletonBirch)

Foucart Fabrice (Carmeuse)

Fuchs Werner (BVK)

Grégoire Damien (Carmeuse)

Habib Ziad (Lhoist)

Hammerschmidt Sebastian (BVK)

Hanzl Pavel (Carmeuse)

Haworth Martin (SingletonBirch)

Kaponen Ulla (Nordkalk)

Marbehant Jean (Lhoist)

McCabe David (Tarmac)

Mengede Martin (Kalk)

Meyer Chris (Singleton Birch)

Moreschi Roberto (Unicalce)

Naffin Burkard (Fels)

O'Callaghan Denis (Clogrennane)

Ohnemüller Frank (BVK)

Pelletier Marc (Lhoist)

Peter Ulrike (Lhoist)

Philipp Gerhard (Baumit)

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Annex 3: Notes

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